Section 1- Design Challenges

Design a Parachute

Brakes in Space

The speeds traveled by spacecraft need to be fast to allow them to leave the earth's gravitational pull. Yet when they land, vehicles must be going much slower for the landing to be safe. How can they slow down?

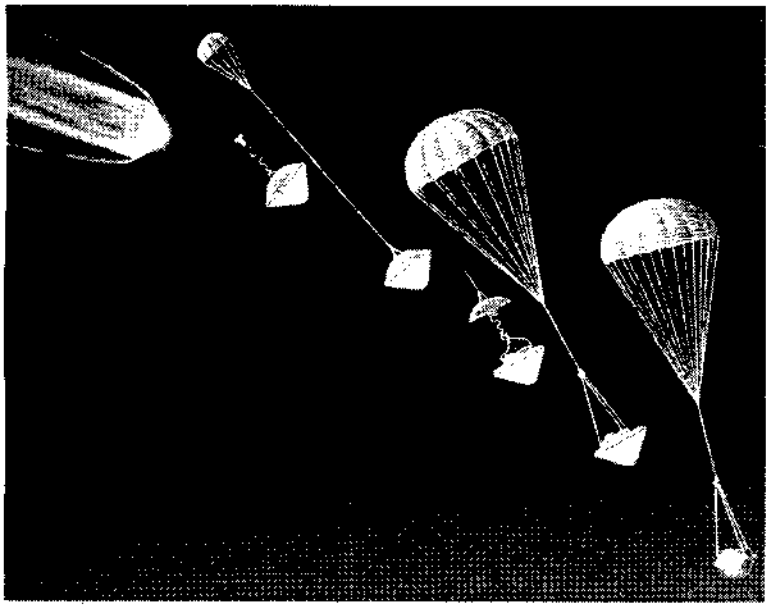
All brakes perform the same function -- apply a force to a vehicle opposite to the overall direction of travel. Different brake systems do this in different ways. Here are six methods used for spacecraft.

Initial Slowdown from High Speeds

1. The Spacecraft and its Heat Shields - As a spacecraft enters an atmosphere, it begins colliding with molecules of gas or air. These collisions cause friction, which slows the craft down. The friction also heats the craft up, and because space vehicles travel at high speeds, this heat of friction could easily burn up the ship. To avoid this catastrophe, heat shields (made of heat resistant materials) are placed on the surfaces of the craft that enter the atmosphere first.
2. Reverse Thrusters - When landing on the moon, where there is no air, the ship fires rockets in a direction opposite to the direction of travel.

Final Slowdown and Landing

3. Parachute to Ground - The Russians used large parachutes and landed their early spacecraft on land.



Artist rendering, NASA

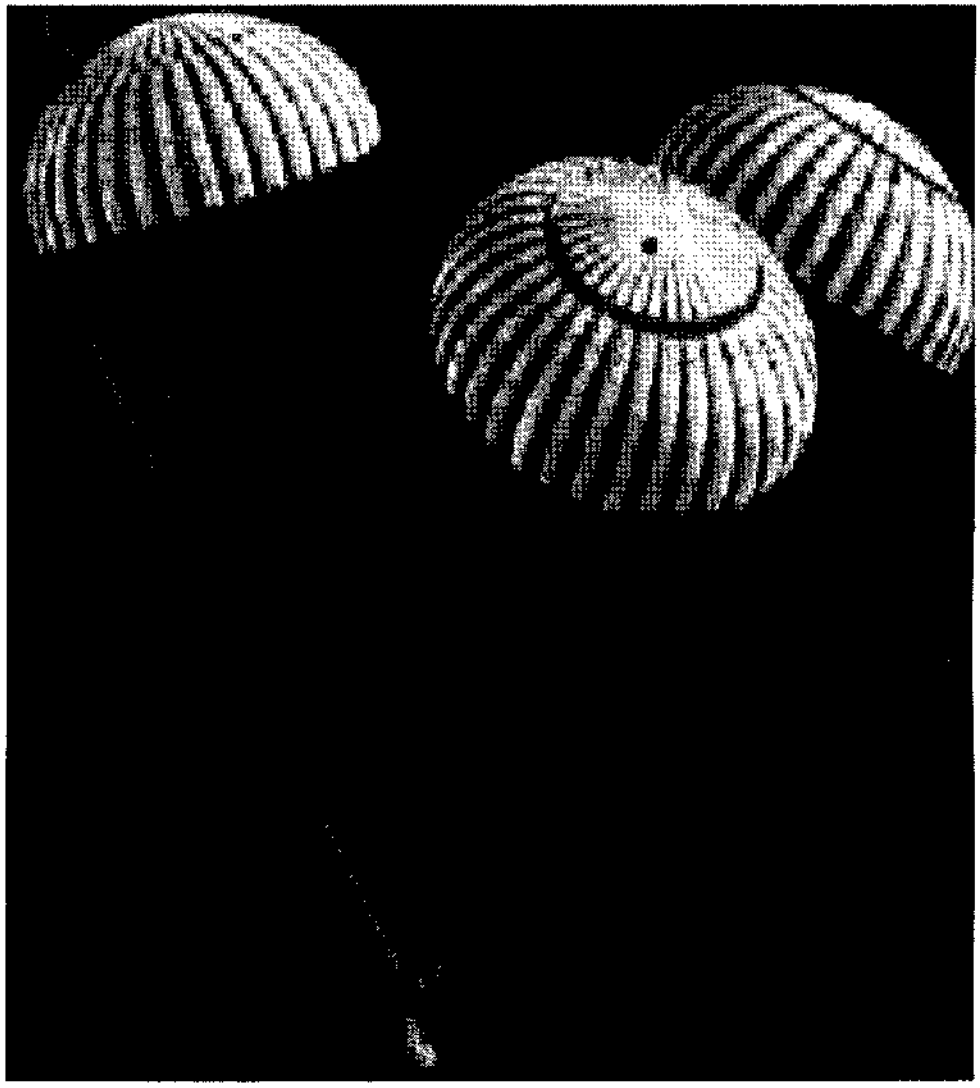
4. Parachute into Water - The Americans used parachutes and the soft cushion of water for landing for their early flights.
5. Gliding - The American and Russian space shuttles each use a plane-like vehicle with landing gear and wheels. This allows the reuse of the ship.
6. Parachute and Bouncing Ball - The Mars Rover used a combination of parachute, reverse thrusters, and for the final descent, inflated cushions, so that the craft could land on the ground without breaking the Rover vehicle inside. (See illustration to left.)

Design a Parachute (cont.)

Parachute Design Challenge Overview

Your challenge will be to design and construct the lightest parachute that can carry a load of two or three nickel-sized metal washers and descend at the slowest speed. To support your design decisions, you will conduct investigations of air resistance using easy-to-make coffee-filter parachutes. Then you will design and build the best parachute you can, making design decisions informed by what you have learned about slowing things down as they fall.

The procedure: (1) First, you'll "mess about" with coffee filters to begin to understand what affects their rate of fall. (2) You'll do whiteboarding as a class to share what you've discovered and to decide what you need to learn more about before designing your best parachute. (3) Each group will design and run an experiment and report results to the rest of the class in a poster session, and, based on results, the class will generate rules of thumb about parachute design. (4) Each group will design its best parachute and present its design plan to the class in a pin-up session. (5) Each group will build, test, and revise their designs, working toward their best parachute. Gallery walks will allow you to help each other along.



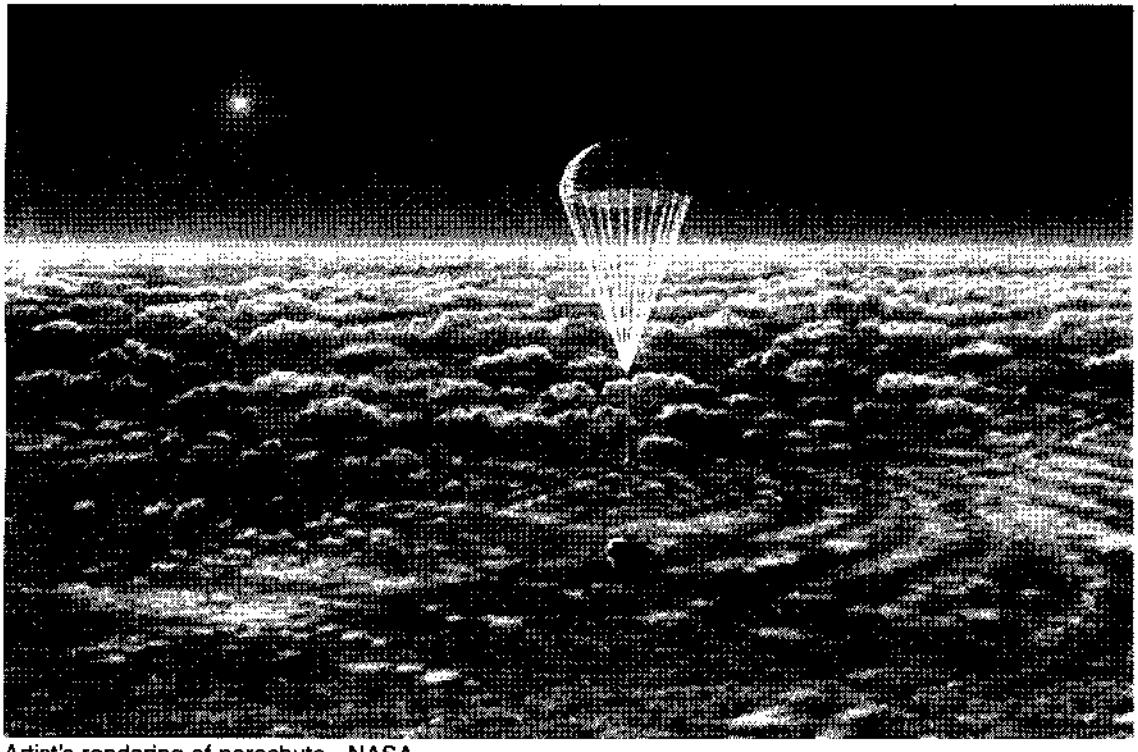
Example of parachutes in motion NASA Photo

Coffee Filters in Motion

Coffee filters have some interesting properties of motion, especially the way they float to earth after being dropped or tossed into the air. Your group will spend a short time learning what affects a coffee filter's falling motion. After you've done this, you'll apply the knowledge gained to your next design challenge, which is to design and build a parachute using coffee filters. Remember the function of a parachute is to slow something down as it falls.

Messing About and Whiteboarding

First, spend some time just dropping coffee filters and observing their behavior as they drop. Then, you may modify the coffee filters to see if you can make them behave more as you'd like them to behave when they are parachutes. Use this time to learn what you can about what affects the filters' rates of fall. After you have done a little of this messing about with the coffee-filter parachutes, you'll probably be curious about some issues you want to find out more about. After messing about, you'll have a whiteboard session where you can share your experience, questions, and ideas with others and decide as a class which controlled investigations to do to find out more.



Artist's rendering of parachute, NASA

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Page 146 Whiteboarding

Coffee Filters in Motion (cont.)

Properties of Parachutes

Parachutes are objects that slow the descent rate, or fall, of an object. Typically parachutes look like large canopies that are tethered, or tied, to a mass hanging below the canopy.

There are several factors or variables that affect the rate at which a parachute will fall. We need to look carefully at two: gravity and air resistance. Gravity is an attraction (force) between all objects in the known physical universe. The earth has a lot of gravity because it is a large mass. The force of gravity causes objects to fall toward the earth's surface.

When we attach a parachute to an object, we are using air resistance to slow the object down. The parachute resists the pull of gravity. How does that work? As it falls through the air, the parachute is colliding with air molecules under it. Air has mass, and it provides a resistance to the falling motion of the parachute and its cargo. This air resistance is known as drag.

Air resistance and gravity work opposite each other on falling objects. If we increase the surface area of a parachute (without changing anything else), we increase air resistance by increasing the number of collisions between the parachute and surrounding air molecules, and it will drop at a slower rate. If we increase the mass of a parachute or the mass of the load it is carrying (without changing anything else), we increase the force due to gravity, and it will fall faster.

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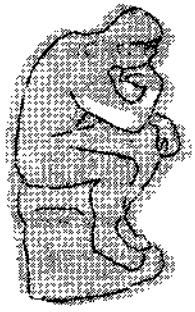
Parachute Science

Reflection Questions



Identifying what you need to learn.

1. What did you observe while messing about?
2. What do you know about how parachutes work?
3. What else do you want to find out about them before designing your best one?
4. For each, how can you find out? What should you try to measure? What can be varied? How can you measure? How will you measure?

Moving Forward

You'll follow this sequence to get to your best parachute:

1. **Designing and Running Experiments:** Each group chooses a question to answer and designs and runs an experiment to answer it. See pages 41 and 43 for hints on experiment design. Remember that a good experiment generates a believable rule of thumb.

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Rules of Thumb, Page 107-109

2. **Presenting Results:** Write up your results on a poster and present it to the class in a gallery walk. As a class, make a list of believable rules of thumb. Send those whose experiments you can't believe back to redo them.

3. **Planning.** Based on what you've learned, plan your best design, and describe it on a large piece of paper. Be sure to describe it so others can understand it well.

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Informed Decision Making

4. **Pin-up session.** Present your design plan to the class. Justify your decisions, citing the result of experiments. Ask for feedback.

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Pin-ups

5. **Construct, test, and iterate.** Be sure to keep records of your designs and the results of testing on Testing My Design Pages. This will help you remember why you made each of your design decisions and will serve as a design history that will show you and the class how your understanding has changed over time. When you present your best ideas to the class, you will be required to offer justification for selecting that particular design. Write down the reasons you tried each design idea and record pertinent data about the parachute and the amount of time it takes to touch down. The teacher will tell you how much time you have for the parachute design and when your report to the class will be due.

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Page 96 Iteration | Page 121 Data Collection

Moving Forward (cont.)

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Gallery Walks

6. **Gallery walks.**

7. **Further iterations and reading about parachutes.**

8. **Final presentation and competition.** In your final presentation, you should demonstrate your parachute, explain your design decisions, and report on why you made each design decision. You'll probably want to make a poster. Report the facts and evidence you used to support each decision. Parachutes will be evaluated by the speed at which they drop. Your group's grade will come from an evaluation of how well your group can explain its decisions.

Lab Report

You have been working on the parachute challenge for some time and you must now take the time to formally review the work you have been performing. Each team was responsible for testing a variable (some may have tested several variables), and each group should have collected data about the effect changing that variable has on the descent time of the parachute.

It is now time to present your work in a lab report. **Individually**, you will write a lab report based on the experiment(s) you performed. Each member of the group must have a copy of the data collected in order to complete this assignment. If your group performed more than one experiment, then you must, individually, pick an experiment to focus on in your lab report.

Each student must write a lab report following this format:

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Experiments

1. **Title:** Provide a cover page, with a title, for your report.
2. **Question/Problem:** State the question your group was investigating. Remember that the focus of this question will be the variable you were testing.
3. **Hypothesis:** What was your prediction about the outcome of the experiment? What effect did you think the variable would have? Why?
4. **Procedure:** Write a detailed procedure of what you did to actually perform the experiment. You can either write the steps as a numbered list, or you may want to report your procedure in paragraph form. Ask your teacher which he or she would prefer you to do.
5. **Data:** Show the data you collected in a neat, organized format. You may want to use a table or chart to display the data you collected.
6. **Data Analysis**: Create a graph or chart that compares the results of all your trials. You may have to calculate some averages in order to create the graph or chart.
7. **Conclusions:** (a) Tell us what you think your data suggests about the effect of your variable. As you changed the variable, what changes did you see in the performance or behavior of the parachute? Refer to the data to support your conclusions.
(b) Also, see if you can relate the variable you investigated to the principles of science we have discussed (like air resistance, mass, forces, and gravity). (c) Finally, give a recommendation of how a team, building a parachute, should incorporate your variable into their design. You might want to put this in the form of a rule of thumb.

Lab Report (cont.)

While each of the people in your group will have identical data, the way you present your experiment and the conclusions you formulate will determine your grade on this assignment. Your teacher will provide you with a grading checklist or rubric to help you understand how your lab report will be graded. Some of your grade will be based on the work you did as a group, but most of your grade will be based on what you do as an individual on this lab report.

Decision Making Revisited

We all make many decisions everyday. Some are relatively trivial: What shall I have for lunch? What shall I wear today? Some are important: How much effort shall I put into my math homework? Should I spend my time reading the book I need to read for English, or shall I go to the movies with my buddies? Some have to do with our relationships with other people: How shall I tell my boyfriend I want to break up? How can I get that cute girl to notice me? Some can have consequences that need to be considered: Shall I spend my money on a birthday present for a friend or shall I buy that CD I want? Some have very major life consequences.

When we recognize that a decision is an important one, we spend some time thinking about what to do. Sometimes we make good decisions, and sometimes we don't.

Engineers and designers are faced with decisions everyday also. The decisions they make effect the products they design and manufacture. The have to worry about whether something they are designing will perform its function well enough, whether its design will allow it to be sold for a reasonable amount of money, whether it is safe enough, whether people will like it, and so on.

To make sure they are doing the best job of designing that they can, they usually follow several guidelines each time they have to make a decision:

1. They list out the constraints that have to be met.
2. They list out the criteria they'd like to meet.
3. They generate several alternative solutions. This often requires research, to see what the possibilities are and to find out how others have solved similar problems.
4. For each alternative, they evaluate to what extent it meets the constraints and criteria. This often involves testing and data collection.
5. Often, testing will show some small problem with an alternative that, if fixed, would allow it to meet constraints and criteria far better. When that happens, they modify that alternative and insert it into the alternatives list.
6. Once they've figured out to what extent each alternative meets the constraints and criteria, they judge which is the best one, using the evidence they've gathered and their judgment of the importance of each criterion to justify their decision.

Decision Making Revisited (cont.)

Did you do some of these things when you were making spending decisions in the first homework assignment? What kinds of decisions did you and your group make when you were designing book supports? Did you do research or testing to inform those decisions? What about when designing the parachute?

The design challenges you'll be working on in the future will require lots of decision making. What materials shall I use? How much force does my propulsion system need to apply? How can I reduce friction? How can I reduce air resistance? We want you to learn to make informed decisions -- informed by research and investigations that allow you to find out how things work and why they work the way they do and by testing and data collection.

Learning by Design™ will help you learn those skills as you work on design challenges. We hope you'll become comfortable enough at informed decision making that you'll naturally make informed decisions whenever life calls on you to make a decision that might have important consequences.

During class today:

Reflect on the decision making you did today while you were working on your parachute design. As best you can, write down the decisions you had to make, the choices you considered for each, what constraints and criteria had to be met, what you decided on, and why you made each decision.

Reflection Questions

Reflect on your parachute decisions again, and try to assess each one.

1. List at least 3 decisions your group made.
2. For each, if you had to do it over again, would you make the same decision? Why or why not?
3. What are the suggestions you would make to your team about doing something differently than has already been decided?

Write these things down, and be prepared to discuss them with your team.