SOCIETY OF PHYSICS STUDENTS SOCK

Science Outreach Catalyst Kit

2003
Spanning Space

Dear SOCK recipient,

Congratulations on taking part in the 2003 SPS Outreach Catalyst Kit (SOCK) project: *Spanning Space*. We are proud to present a **novel, nationwide space themed science experiment** in which *you*, as a SOCK project participant, will be taking part! As a complement to this experiment, we have also included a stellar star unit. We hope the variety and depth of the outreach materials will be useful both amongst chapter members and in the community.

As the name implies, the SOCK is meant to act as an outreach catalyst. This outreach can be done amongst SPS members, at the college or university and in the community. This instruction manual provides explanations of the materials included in the SOCK and sample lesson plans. These ideas are not a complete list of uses for the SOCK, but, rather, a jumping off point from which your chapter can further develop lesson plans. We encourage you to creatively expand the use of the SOCKs, and to let us know about such innovations.

The first lesson, "Landing on Mars," marks the launch of a national SPS science experiment of some relevance to NASA's Mars Pathfinder Lander. It involves dropping cylinders of different sizes and centers of mass, and determining how they land. Our goal is for **every SOCK recipient to perform this experiment with its chapter members and to send us the results**. Every chapter who has volunteered to take part in the SOCK project has committed to doing so.

The second lesson, "Exploring the Stars," includes a discussion of light from several different perspectives. We have included some of the popular elements from earlier versions of the SOCKs (rainbow glasses, different light sources etc.), but have added a few new twists. We explain the color of stars, the order of colors in rainbows and some other interesting phenomena.

We hope that these lessons will find numerous uses in your chapter, college/university and community. Since we are always interested in improving the SOCKs so that we can better serve you, your feedback is of utmost importance to us. This is why we have asked each SOCK recipient to agree to **complete and return a SOCK feedback form** (to be distributed later) detailing the use of the SOCK and suggestions for improvement.

Thank you very much for taking part in this year's SOCK project. Have fun exploring space, and feel free to address questions or comments to sps@aip.org.

Good luck, and stay in touch!

Sincerely,

Stacey Sude and Ashley M. Smith
2003 AIP/SPS outreach interns

Table of Contents

This manual was prepared by Stacey Sude and Ashley M. Smith,
AIP/SPS summer 2003 interns.

SOCKs, A History

The SOCK program began in 2001 as part of an outreach effort by the Society of Physics Students. Its goal is to provide physics lesson ideas and demonstration materials to Society of Physics Students (SPS) chapters on college campuses across the United States. The lessons in the SOCKs can be used both within the chapters themselves and in local classrooms.

Each SOCK contains lessons and materials that can be adjusted for age group. Qualitative activities for younger students are possible, as are higher-level activities for more advanced high school students. The lessons can be used within the SPS chapters themselves, on college/university campuses and in local classrooms.

SPS intern Mark Lentz put the first SOCK together in 2001. Called *Rainbow Suite*, it elucidated different properties of rainbows. The second SOCK, constructed in 2002 by SPS interns Lauren Glas and Jason Tabeling, bore the title *Dimensions in Physics*. It explored geometry in a variety of contexts.

A 2003 creation of Stacey Sude and Ashley M. Smith, the third and latest SOCK, *Spanning Space*, is the first SOCK to include both experimental and outreach components. This SOCK also contains some of the more popular elements from the first two SOCKs.

The SOCK project is supported by SPS, its associated honor society, Sigma Pi Sigma (ΣΠΣ) and the University of Maryland's Materials Research Science and Engineering Center's (MRSEC) GK 12 outreach program. In addition, NASA's Sun-Earth Connection Education Forum has generously donated several space related outreach materials included in the back of this instruction manual.

SPS is a professional society for physics students and their mentors. It operates within the American Institute of Physics (AIP)—an umbrella organization for ten other professional science societies. The University of Maryland's MRSEC GK 12 program is funded by the National Science Foundation (NSF).

What to buy and where to go: Materials

To make the SOCKs even more user friendly, we have included all of the materials (except classroom materials, such as paper or scissors) necessary for experimental and outreach activities in *Spanning Space.* In the event that these materials break or get lost, or if your chapter decides it needs more, however, we have included a list of vendors for each item included in this year's SOCK.

If you did not receive one of the products listed here, please contact SPS to have it sent to you.

Landing on Mars:

Product	Quantity	Vendor
50 wooden cylinders, ½ drilled, 1 ½" diameter	50 total, 10 each of 5 different lengths	American Wood Working Co, Inc. (608) 297-2131
Bed sheet	1	

Exploring the Stars:

Product	Quantity	Vendor

NASA's Niche:

Product	Quantity	Vendor
Venus Transit bookmarks	5	All Materials provided free of charge by: NASA's Sun-Earth Connection Education Forum http://sunearth.gsfc.nasa.gov/ Contact: Carolyn Ng carolyn.ng@gsfc.nasa.gov
Space science education resource directory postcards	5	
Mars mini-posters	5	
about Plasmas information sheet	1	
What Causes the Northern Lights? brochure	1	

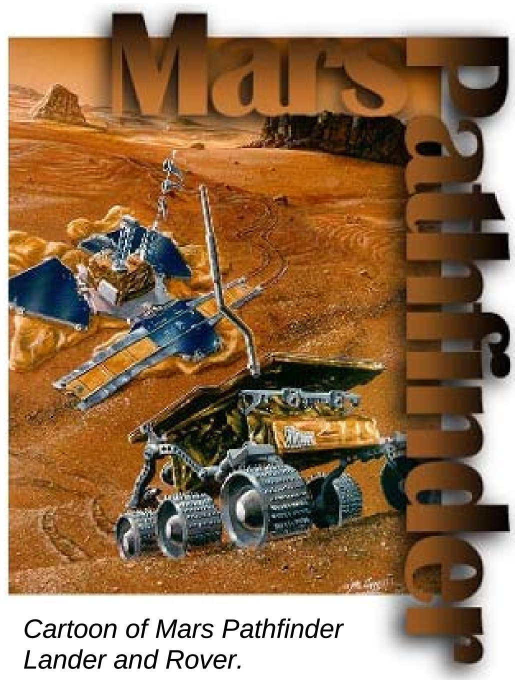
Unit I: Landing on Mars

A science experiment for all ages

This cylinder dropping experiment marks the launch of a new, national science experiment! In the first three pages, this unit contains a brief introduction to Mars, a discussion of the aim of the experiment, and an overview of a lesson that SPS members might lead. This is followed by a detailed lesson plan that can be read by those who would like a more in depth look at possible outreach ideas.

I. Mission to Mars

Entering the martian atmosphere 125 km. (80 mi.) above the surface a spacecraft slows from a whopping 7.5 km/s (16780 mph) to a mere 400 m/s (900 mph) as it whizzes past air molecules and draws closer to the red planet's surface. The pyramid shaped Pathfinder Lander bounces a few times and comes to rest at a random orientation. Motors turn the craft upright. Note: for a complete description of the Pathfinder Lander visit http://mars.jpl.nasa.gov/MPF/mpf/edl/edl1.html.



Cartoon of Mars Pathfinder Lander and Rover.

II. Falling Objects

The landing behavior of different shapes is a little explored branch of physics that has numerous applications, such as the Mars Pathfinder mission. The cylinder dropping experiment in this unit examines the way cylinders of different sizes and centers of mass land when they fall.

New Science: A national effort

SPS chapters across the country will drop cylinders with their members, peers and communities. These will be sent to the national SPS office for analysis.

While some theoretical work has been done on this question[1], there exists little published experimental work. With this experiment we hope to elucidate the landing behavior of objects dropped with random orientation—-objects such as the pioneering Pathfinder spacecraft. Ultimately, as the knowledge about how things land grows, one can imagine eliminating problems such as the need to install motors in the Pathfinder Lander.

[1] *The dropping of a cylinder* H. Bondi Eur. J. Phys. 14 (1993) 136-140.

III. Nuts and Bolts: In the classroom

Mars: The Red Planet

Materials:

- 50 wooden cylinders of 5 different lengths (10 cylinders per length)
- Half of the cylinders are solid, half have holes drilled halfway through
- Bed Sheet
- Scissors
- Paper

Note: The solid and drilled cylinders represent different centers of mass

Lesson:

1. Catch the group's attention with NASA and the Mars Pathfinder Lander.
2. Explain that this is new science. The data is for a national experiment.
3. Choose one or more topics of discussion and introduce it. Topics may include:

- scientific method
- area
- tabular analysis
- statistics
- aspect ratio
- angular momentum
- center of mass
- graphical analysis

Note: In a pilot lesson with students going into 9th grade, the first four topics worked well. A sample, detailed lesson plan is provided in the following section.

4. Relate topic(s) to cylinders. (ex. Find the surface area of the cylinders by cutting out a piece of paper that covers the rolling side and one that covers the flat side. Compare the areas.)
5. Have students form hypotheses based on this discussion.
6. Write hypotheses on the board next to students' names
   (ex. "Zuya's hypothesis: Cylinders with more flat area will land upright.")
6. Include every suggested hypothesis (even those that may be incorrect).

Experiment:

1. Push the desks to the side of the classroom (about a 6'x6' area is needed). The landing surface should be hard and smooth (like the vinyl commercial tiles typical of many classroom floors). Cover the floor with the sheet provided in the SOCK.
2. Distribute one set of 5 cylinders to each student or pair of students.
3. Ask students to drop the 5 cylinders 4 times from a height of 1 m.

4. Students should record their results on the data sheets from this manual.
5. Have students record number of cylinders dropped each time (generally 5), number of rolling side landings and number of upright landings.

Note: If they are uncertain about any drop, they should omit it from their data explain their uncertainty in the comment box. If the cylinders bump into each other or into something else because we assume this bump is random.

6. Students can drop several different sets of cylinders and compare results.

Analysis:

1. Data can be analyzed in a table or graph, depending on educational level.
2. Tables and graphs may compare:
   - Cylinders of different length
   - Cylinders with different centers of mass

Mission Missive: A great way to end the lesson is to ask students to write a mock missive to NASA recommending a design for their next spacecraft, and justifying that recommendation.

IV. Sample Lesson Plan

This lesson was written to give you an idea of what you might want to say to students. It is geared toward students in 7th and 8th grade and contains a sample script, as well as lesson notes.

The words in bold are suggestions for what the SPS member leading the lesson might say.

Introduction to space

Who here is interested in space? To which planet did we send spacecraft to investigate? Who can tell me what NASA's mission was called?

Hopefully someone will say "The Mars Pathfinder Mission." If the grade level is low enough, you might also have to ask whether anyone knows what NASA is (National Aeronautics and Space Administration).

Much planning went into the Mars Pathfinder mission. One of the most basic aspects of the Mars Pathfinder Lander was its pyramid shape. Scientists did not know which side it would land on after coming to rest on the planet's surface, so they installed motors to turn it right side up.

This is both costly and time consuming, however, so it would be better if we knew beforehand what side the spacecraft would land on. Today we are going to talk about predicting how shapes land, specifically cylinders.

No one really knows how cylinders land. Some theoretical studies have been done, but to our knowledge there is little to no experimental work in this area. Today we're going to change this by dropping several. We will contribute our results to a national science experiment.

Shapes and cylinders

What types of cylinders do you see in every day life?

- Coins
- Rolls of tape
- Tires
- Batteries
- CDs
- Straws
- Cans
- Poster holders
- Pipes
- Pencils

When dropped, which side do cylinders land on (rolling or upright)?

- Take a vote. When they come to a decision (or to multiple decisions) write it one the board "Julie's hypothesis:…"
- If they think that cylinders land on their rolling side, show them a long, narrow cylinder (paper towel roll, poster holder) and drop it.
- If they think that the cylinders land upright, show a flat cylinder (like a coin or roll of tape) and do the same thing.
- Now show a different cylinder (either the tape/coin or the poster holder/paper towel roll—whichever you didn't use).

Are you still sure about your decision? Do cylinders always land the same way? Do they land differently? How do they land?

Drop the second cylinder and see whether it lands on the same side (it shouldn't).

Explain that it's easy to make assumptions that might not necessarily be true in all cases. One empirical example is not "proof" that a particular hypothesis is correct. But you can disprove a hypothesis with a counterexample.

Area

What made these two cylinders different from each other?

They will probably answer size and shape, although the cylinders differ in other ways, such as

- Material
- Color
- Solid vs. half hollow

Although all of these properties may not affect the landing behavior of a cylinder, it is nonetheless important to observe these differences.

So if size and shape was the biggest difference between the two cylinders, what can we say about the way they fall?

Possible hypotheses include "Tall, skinny cylinders land on their rolling side, whereas short, fat cylinders land upright," and "Big cylinders land on the rolling side, whereas small cylinders land upright." Note that this conclusion may not be appropriate.

What specifically affects a cylinder's landing behavior? What is area?

Students might respond:

- height x width

- pi r squared
- the region a shape covers, etc.

Be sure that they are familiar with the reason why area is actually called area… it refers to the amount of space or area covered by a particular shape.

How would area affect which side a cylinder lands on?

Trying to elicit the response that the side (rolling or upright) with the larger area will be the side on which the cylinder lands.

Now let's compare the areas of the cylinders that you'll be dropping.

- Pass out a cylinder, paper and scissors to each student.
- Ask them to trace the flat circular side of their cylinder and cut it out.
- They should then cut out a rectangular strip of paper that will wrap around the rolling side of the cylinder (representing the area of the rolling side)
- Have students visually compare the two areas.
- If it is difficult to tell which is bigger, students can cut the circle into pieces and place them on the rectangle to see which takes up more space.
- Ask students to predict which side they think their cylinders will land on.

The drop

It's time to drop the cylinders. In groups of two or three take turns dropping all five of your cylinders at once and filling out these data sheets. Be sure to specify which the code on the side of the cylinders. This code is necessary for your data to be included in the national science experiment.

- The cylinders should be dropped from 1 m.
- Record: # of cylinders dropped, # of rolling side landings, # upright landings.
- Record any uncertainties in a separate category.
- If cylinders hit other objects when they bounce, this hit is random and will not adversely affect the data
- Students can exchange cylinders depending on time constraints.

Analysis

The students can work in small groups or as a class to makes tables or graphs, of the data.

For a table, set up two columns (one for solid, one for drilled cylinders). For graphs, draw two different lines on the same graph, for solid and drilled cylinders. Tables and graphs may include:

- Proportion of rolling landings (to total landings) for different heights
- Proportion of rolling landings (to total landings) for different aspect ratios
- Proportion of rolling landings (to total landings) for different areas of the rolling side
- Number of rolling landings for different heights
- Number of rolling landings for different aspect ratios
- Number of rolling landings for different areas of the rolling side

If you use the absolute number of rolling landings rather than proportion, make sure that all of the cylinder sizes were dropped the same number of times.

Compare the hypotheses with the graphs/tables. Modify them if necessary.

Students often make hypotheses such as "Cylinders with more rolling side area land on their rolling side." To introduce the statistical nature of physics, change this to: "Cylinders with more rolling side area *often* land on their rolling side."

Conclusion

Based on our tables/graphs, and what you discovered when you dropped your own cylinders, write a brief note to NASA making a recommendation for the shape of their next spacecraft, its distribution of weight, relative dimensions and where the top should be. Be sure to justify your recommendations with experimental results and your interpretation of these results.

This strengthens a student's realization that science experiments performed in school do have applications outside of the classroom. It is also a good way for students to review what they have learned during the lesson. Teachers can assess the strengths and weaknesses of the lesson and identify areas where more classroom time should be spent.

Angular momentum and Center of Mass

Since this lesson was geared toward students with little or no physics background, it did not include angular momentum or center of mass. The cylinder dropping experiment lends itself well to lessons with more advanced students.

Angular Momentum: In preliminary testing of the cylinders it seems that introducing initial angular momentum (spinning the cylinder when dropping it so that it rolls when it lands) causes a disproportionate number of rolling landings.

The angular momentum of the very thin, coin-shaped cylinders tends to keep them on their rolling side for a short while after they land, despite aspect ratio predictions to the contrary. These competing effects make interesting fodder for discussion.

Center of Mass: Although no pilot lessons were done on cylinders with different centers of mass, you can do a lesson where students calculate the center of mass of the drilled cylinders and compare it with the solid cylinders. The students can then decide how center of mass affects the dropping behavior of the cylinders.

Cylinder Dropping Data Sheet (solid cylinders):

Your name: ____________________

1. Record the code from the side of the cylinder.
2. Record the landing surface.
3. Hold the cylinders (randomly oriented) at a height of 1 m above the ground.
4. Drop all 5 cylinders at once.
5. Record the number of cylinders dropped, the number that land on their rolling sides and the number that land upright.
6. If there are uncertainties, put the number of cylinders and an explanation in the box column labeled Comments/ number uncertain. (If your cylinder bumps into something, you, as the scientist, must determine whether you think that the data should be included, or whether the impact affected the cylinder in a non-random way.)

Code on Cylinders:________ **Height dropped from**: 1m

Surface:

- ❑ Tile or similarly hard, smooth surface covered with a bed sheet.
- ❑ Other: ____.

Number of cylinders dropped	Number of upright landings	Number of rolling landings	Comments/ number uncertain

Cylinder Dropping Data Sheet (drilled cylinders):

Your name: ____________________

1. Record the code from the side of the cylinder.
2. Record the landing surface.
3. Hold the cylinders (randomly oriented) at a height of 1 m above the ground.
4. Drop all 5 cylinders at once.
5. Record the number of cylinders dropped, the number that land on their rolling sides, the number that land drilled side up and the number that land undrilled side up.
6. If there are uncertainties, put the number of cylinders and an explanation in the box column labeled Comments/ number uncertain. (If your cylinder bumps into something, you, as the scientist, must determine whether you think that the data should be included, or whether the impact affected the cylinder in a non-random way.)

Code on Cylinders:________ **Height dropped from**: 1m

Surface:

- ❑ Tile or similarly hard, smooth surface covered with a bed sheet.
- ❑ Other: ____.

Number of cylinders dropped	Number of drilled side up landings	Number of undrilled side up	Number of rolling landings	Comments/ number uncertain

Unit II: Exploring Stars: Spectral Speculations

Nuts and Bolts: In the classroom

Materials (included in SOCK):

- Keychain microlights, assorted colors
- Keychain UV microlight
- UV-detecting beads
- Phosphorescent vinyl square
- Keychain laser
- Variable intensity lamp
- Glowsticks
- Prism
- Diffraction grating
- Diagrams of prism and diffraction grating dispersion

Materials (not included in SOCK):

- Vapor tubes
- Any other available light sources (fluorescent lights, street lamps, the sun, neon signs)

Sample lesson I:

What do you know about rainbows? Does anybody know how rainbows are formed?

1) Elicit preconceived notions about rainbows and guide students to the concept that rainbows are created when light passes through a water droplet and is separated into its spectrum.

2) Hand out glasses and instruct students to view a white light with them. As students begin to perceive rainbows, explain that the glasses are like water droplets in that they separate light into a spectrum. Show diffraction gratings to illustrate the phenomenon.

3) Turn on numerous light sources and allow the students to view them. Then ask them to record the colors (and whether continuous or discrete) that they see. Next, hold a Spectral Scavenger Hunt. Offer a prize to the person who locates the most spectra 1st. After the hunt, explain that scientists use spectroscopy to identify certain substances. Eg. Astronomers use it to identify the substances that make up other planets.

4) Next turn off all the other sources and focus on the varying intensity source. Tell the students to observe closely as intensity varies. Ask the students to observe which color appears to diminish as the intensity of the light decreases. They should notice that blue diminishes. Explain that when the intensity is greater, the light is hotter and that more red denotes a cooler light and blue a hotter. Link to stars. Astronomers know that when you look up into the night sky, red stars are cooler and blue hotter.

Sample lesson II:

1) Prompt students' prior experience/knowledge by asking them about spectra in their every day lives. Ask whether anyone knows how a rainbow is formed in the sky by rain, by a water hose, by a crystal. Some students may have previously heard an explanation of prism dispersion. Ask the students if they have noticed an order to the colors in the rainbows and what that might be. Introduce ROYGBIV and depending on age level, discuss wavelength and energy.

2) Give students a demonstration of dispersion with a prism. Link this demo to the everyday refraction phenomena mentioned by the students. Ask the students to determine which color is bent farthest from the source of light. Then give a demonstration of dispersion with a diffraction grating. Ask the students which color is now farthest from the source of light. The answers should be opposite. ROYGBIV vs. VIBGYOR. Use diagrams of prism and diffraction grating dispersion to emphasize the reversal.

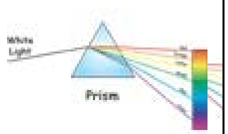


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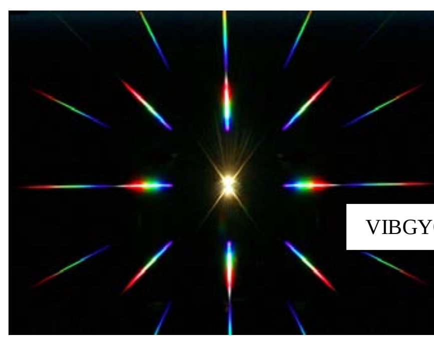
Figure 1: Prism Spectrum



VIBGYOR

Figure 1: Double-Axis Diffraction Grating Spectrum

NASA's Niche

In addition to SPS experiment and outreach materials, this SOCK contains information and outreach materials from NASA's Sun-Earth Connection Education Forum. These materials are not directly integrated into either unit, but they augment the information in these lessons. They contain a wealth of topics that are of interest to any space savvy student.

Here's a summary of what we have included:

***Venus Transit* bookmarks:** Not seen since 1882, Venus Transit occurs when the Venus travels across the face of the sun. To celebrate the upcoming Venus Transit (June 8, 2004), NASA has launched an outreach effort with resources for students and teachers. The bookmarks sport website and contact information for this project. Check it out yourself and leave a bookmark or two with the teachers for whom you do the outreach!

***Space science education resource directory* postcards:** These postcards list NASA resources for general space education. Like the bookmarks, these can be both for SPS use and as a resource for the teachers with whom SPS works.

Mars mini-posters: Cool photos with fun facts on Mars, these mini-posters make great decoration for SPS lounges and great prizes for outreach events.

***about Plasmas* information sheet:** Representing over 99% of the universe, plasmas are a fourth state of matter containing charged and uncharged particles. This sheet provides a general overview of plasmas, which comprise stars such as our sun. This is a great way to supplement the "Exploring the Stars" unit in this SOCK.

***What Causes the Northern Lights?* brochure:** Another way to expand the "Exploring the Stars" unit, this brochure explains what causes auroras, what they look like, where they can be seen, and why they are important.

The Sun-Earth Connection Education Forum provides these materials free of charge. To order more, contact Carolyn Ng at carolyn.ng@gsfc.nasa.gov or visit their website http://sunearth.gsfc.nasa.gov/.