

Module 2: Motion

3rd Grade

About the Instructions:

This document is intended for use by classroom teachers, SciTrek leads, and SciTrek volunteers. The document has been composed with input from teachers, leads, volunteers, and SciTrek staff to provide suggestions to future teachers/leads/volunteers. The instructions are not intended to be used as a direct script, but were written to provide teachers/leads/volunteers with a guideline to present the information that has worked in the past. Teachers/leads/volunteers should feel free to deviate from the instructions to help students reach the learning objectives of the module. Places in which you can be creative and mold the program to meet your individual teaching style, or to meet the needs of students in the class are: during class discussions, managing the groups/class, generating alternative examples, and asking students leading questions. However, while running the module make sure to cover all the material each day within the scheduled 60 minutes. In addition, no changes should be made to the academic language surrounding questions or the question activity.

Activity Schedule:

There are no scheduling restrictions for this module.

Day 1: Question Assessment/Technique/Observations/Reproducibility Discussion/Variables (60 minutes)

Day 2: Question Activity/Questions/Materials Page/Experimental Set-Up (60 minutes)

Day 3: Technique/Procedure/Results Table/Experiment (60 minutes)

Day 4: Graph/Results Summary/Poster Making (60 minutes)

Day 5: Poster Presentations (60 minutes)

Day 6: Question Assessment/Draw a Scientist/Tie to Standards/Content Assessment (60 minutes)

The exact module dates and times are posted on the SciTrek website (www.chem.ucsb.edu/scitrek/elementary) under the school/teacher. The times on the website include transportation time to and from the SciTrek office (Chem 1204). Thirty minutes are allotted for transportation before and after the module, therefore, if a module was running from 10:00-11:00, then the module times on the website would be from 9:30-11:30.

Student Groups:

Students are divided into four groups of approximately five students each, for the entire module. One volunteer is assigned to help each group. We find groups work best when they are mixed levels and mixed language abilities.

NGSS Performance Expectation Addressed:

3-PS2-2 Make observations and/or measurements of an object's motion to provide evidence that a pattern can be used to predict future motion.

Common Core Mathematics Standard Addressed:

3.NF-1 Understand a fraction $\frac{1}{b}$ as the quantity formed by 1 part when a whole is partitioned into b equal parts; understand a fraction $\frac{a}{b}$ as the quantity formed by parts of size $\frac{1}{b}$.

Learning Objectives:

1. Students will know an object's motion is predictable and will be able to predict the outcome of an experiment based on previous data.
2. Students will know the importance of repeating their experiments.
3. Students will be able to find the median number of a given set of numbers composed of an odd number of data points.
4. Students will be able to generate at least two testable questions and recognize when questions are not testable by science.
5. Students will be able to suggest revisions for questions that are not testable by science in order to make them testable.
6. Students will be able to list at least one way they acted like scientists.

Classroom Teacher Responsibilities:

In order for SciTrek to be sustainable, the program needs to work with teachers on developing their abilities to run student-centered inquiry-based science lessons on their own in their classrooms. As teachers take over the role of SciTrek lead, SciTrek will expand to additional classrooms. Even when teachers lead the modules in their own classrooms, SciTrek will continue to provide volunteers, and all of the materials needed to run the module. Below is a sample timeline for teachers to take over the role as the SciTrek lead.

*Groups are made up of approximately five students.

1. Year 1
 - a. Classroom teacher leads a group (Role: Group Lead; this role is referred to as a volunteer in these instructions)
2. Year 2
 - a. Classroom teacher co-leads the modules with a SciTrek staff member (Role: Co-Lead)
 - i. Classroom teacher will be responsible for leading entire class discussions (Ex: question activity).
 - ii. Classroom teacher will be responsible for time management.
 - iii. Classroom teacher will be responsible for overseeing volunteers and helping any groups who are struggling.
 - iv. Classroom teacher will be responsible for all above activities. The SciTrek co-lead will only step in for emergencies.
 - v. The SciTrek co-lead will run the tie to standards activity.
3. Year 3 and beyond
 - a. Classroom teacher leads the modules (Role: Lead)
 - i. Classroom teacher will be responsible for leading entire class discussions (Ex: question activity).
 - ii. Classroom teacher will be responsible for time management.
 - iii. Classroom teacher will be responsible for overseeing volunteers and helping any groups who are struggling.
 - iv. A SciTrek staff member will co-lead the tie to standards activity with the classroom teacher for year 3.

SciTrek staff is counting on teacher involvement. Teachers should notify the SciTrek staff if they will not be present on any day(s) of the module. Additional steps can be taken to become a SciTrek lead faster than the proposed schedule above. Contact scitrekelementary@chem.ucsb.edu to learn more.

In addition, teachers are required to come to UCSB for the module orientation, approximately one week prior to the start of the module. Contact scitrekelementary@chem.ucsb.edu for exact times and dates, or see our website at chem.ucsb.edu/scitrek/elementary under your class' module times. At the orientation, teachers will go over module content, learn their responsibilities during the module, and meet the volunteers who will be helping in their classroom. If you are not able to come to the orientation at UCSB, you must complete an online orientation. Failure to complete an orientation for the module will result in loss of priority registration for the following year.

Prior to the Module (at least 1 week):

1. Come to the SciTrek module orientation at UCSB.

During the Module:

If possible, have a document camera available to the SciTrek lead every day of the module. If you do not have a document camera, please tell a SciTrek staff member at orientation.

Days 1 and 3:

Have four floor spaces available for students. Each group will need a ~5 ft x 2 ft floor space for the ramp set-up, as well as additional space for approximately five students to sit.

Days 2-4:

Have students' desks/tables moved into four groups and cleared off. This ensures each student has a desk during SciTrek activities, and students can begin the module as soon as SciTrek arrives.

Days 5-6:

Have students' desks/tables cleared off. The desks/tables do not need to be moved into groups.

Scheduling Alternatives:

Some teachers have expressed interest in giving the students more time to work with the volunteers throughout the module. Below are options that will allow the students more time to work with the volunteers. If you plan to do any of the following options, please inform the SciTrek staff no later than your orientation date (approximately one week before your module, exact orientation times are found at: chem.ucsb.edu/scitrek/elementary). This will allow the SciTrek staff to provide you with all needed materials.

Day 1:

If you would like to have more time for your students to make observations and generate variables, you can do one or both of the following activities, **before** SciTrek arrives:

- 1) Question assessment
- 2) Technique activity

Day 2:

If you would like to have more time for your students to generate testable and non-testable questions and design their experiments, you can go over the question activity, **before** SciTrek arrives.

Day 3:

If you would like to have more time for your students to perform their experiments, you can do the technique activity, **before** SciTrek arrives.

Day 5:

If you would like to have more time for your students to discuss their experiments during poster presentations, you may take more time for each presentation and finish the presentations, **after** SciTrek leaves.

Day 6:

If you would like more time for the tie to standards activity, you may give the question assessment, **before** SciTrek arrives.

Materials Used for this Module:

1. Outdoor Carpet (Home Depot part number: Elevation Stone Beige 0000-512-400) cut into 6 ft x 2 ft pieces. One of the 6 ft x 2 ft outdoor carpets is marked with a permanent marker to show the 50 cm, 100 cm, and 150 cm mark. This carpet is only used on the Tie to Standards day. In addition, the appropriately sized outdoor carpet is hot glued to all of the ramps. See description listed under Particle Board.
2. Shag Carpet (Home Depot part number: Palmetto Sandalwood 0000-763-088) cut into 100 cm x 30 cm pieces. In addition, 50 cm x 30 cm pieces of the shag carpet are hot glued to 50 cm x 30 cm ramps for the initial observation.
3. AstroTurf (Home Depot) cut into 125 cm x 30 cm pieces. In addition, 50 cm x 30 cm pieces of AstroTurf are hot glued to 50 cm x 30 cm ramps for the initial observation and the Tie to Standards. One of the 125 cm x 30 cm AstroTurf pieces is marked with masking tape and a permanent marker. At 50 cm there is a mark that says 100 cm, and at 100 cm there is a mark that says 150 cm (the units are 50 cm off because the ramp is the initial 50 cm). This material is only used on the Tie to Standards day.
4. 0.5 in Particle Board (Home Depot) cut to 45 cm x 30 cm, 50 cm x 30 cm, 55 cm x 30 cm, 60 cm x 30 cm, 65 cm x 30 cm, 70 cm x 30 cm, 75 cm x 30 cm, and 80 cm x 30 cm, 100 cm x 30 cm. All boards have outdoor carpet hot glued onto one of the sides except some of the 30 cm x 65 cm (these boards are used for ball stops) and the 100 cm x 30 cm (these boards are used for the Tie to Standards) boards.
5. Rulers (Office Depot part number: 21215472)
6. MyChron Timers (Fisher Part Number: S65330) and replacement batteries (Fisher Part Number: 50-212-755)
7. 152 cm/60" flexible measuring tape (ETA hand2mind Part number: IN524)
8. 300 cm/120" tailor craft flexible ruler tape measure yellow by Amico (Amazon)
9. Large Binder Clips 2" size with 1" capacity (Staples part number: 329502)
10. Lab Jacks 8 in x 8 in (Fisher Part Number: S63082)
11. Wood ramp holders. These are made by cutting a 4"x4" 12 cm tall and then cutting the top to a 14° angle on the top or by cutting a 4"x4" 21 cm tall and then cutting the top to a 24° angle. The backs of the wood ramp holders are covered with a .5" board that sticks 3.5" above the top. See picture below.



12. Digital Scale (OHAUS, max weight: 2000g, readability: 1 g, Model No. H-2715) (Fisher Part Number: S40242-1)
13. Plastic Handmade Balls
 Masses of 27 cm circumference balls: ~55 g, ~100 g, ~165 g, ~200 g, ~265 g, ~305 g, ~360 g
 Circumferences of ~200 g gram balls: 18 cm, 21 cm, 24 cm, 27 cm, 30 cm, 33 cm

All printed materials used by SciTrek (notebooks, materials pages, picture packet, poster parts, instructions, and nametags) can be made available for use and/or editing by emailing scitrekelementary@chem.ucsb.edu.

Types of Documents:

Notebook:

One given to every student and is filled out by the student. The lead will use a notebook to write in as an example for students. The notebook the lead uses is referred to as the class notebook in these instructions.

Notepad:

One given to every group and is filled out by the volunteer. In these instructions, the examples are narrower and taller than the notebook pages.

Picture Packet:

One per class that, if needed, the lead fills out. In these instructions, the examples are labeled, and, if applicable, filled out in blue.

In these instructions, all other example documents are labeled.

Day 1: Question Assessment/Technique/Observations/Reproducibility Discussion/Variables

Schedule:

- Introduction (SciTrek Lead) – 2 minutes
- Question Assessment (SciTrek Lead) – 5 minutes
- Technique (SciTrek Lead) – 10 minutes
- Observation Discussion (SciTrek Lead) – 2 minutes
- Observations (SciTrek Volunteers) – 15 minutes
- Reproducibility Discussion (SciTrek Lead) – 8 minutes
- Variable Discussion (SciTrek Lead) – 2 minutes
- Variables (SciTrek Volunteers) – 13 minutes
- Wrap-Up (SciTrek Lead) – 3 minutes

Materials:

(4) Volunteer Boxes:

- | | | |
|---|---|--|
| <input type="checkbox"/> Student nametags | <input type="checkbox"/> (2) Pencils | <input type="checkbox"/> (2) Green balls (27 cm circ., ~200 g) |
| <input type="checkbox"/> (7) Notebooks | <input type="checkbox"/> (2) Grease pencil | <input type="checkbox"/> Measuring tape (152 cm) |
| <input type="checkbox"/> Volunteer instructions | <input type="checkbox"/> Ruler | <input type="checkbox"/> Measuring tape (300 cm) |
| <input type="checkbox"/> Picture of experimental set-up | <input type="checkbox"/> (7) Timers | <input type="checkbox"/> Large binder clip |
| <input type="checkbox"/> Volunteer lab coat | <input type="checkbox"/> (2) Wood ramp holders (13 cm tall) | |

Other Supplies:

- | | | |
|---|--|---|
| <input type="checkbox"/> (4) Notepads | <input type="checkbox"/> (4) Ball stop boards (65 cm x 30 cm) | <input type="checkbox"/> (4) Boards (50 cm x 30 cm) with outdoor carpet |
| <input type="checkbox"/> (4) 6 ft x 2 ft carpet | <input type="checkbox"/> (4) Boards (50 cm x 30 cm) with shag carpet | <input type="checkbox"/> (4) Pieces of shag carpet (30 cm x 100 cm) |
| <input type="checkbox"/> Box with 4 electronic scales | | |

Lead Box:

- | | | |
|---|--|--|
| <input type="checkbox"/> (3) Blank nametags | <input type="checkbox"/> (25) Question assessments | <input type="checkbox"/> (4) Timers |
| <input type="checkbox"/> (3) Extra notebooks | <input type="checkbox"/> Time card | <input type="checkbox"/> (2) Green balls (27 cm circ., ~200 g) |
| <input type="checkbox"/> Lead instructions | <input type="checkbox"/> (2) Pencils | <input type="checkbox"/> Measuring tape (152 cm) |
| <input type="checkbox"/> Motion picture packet | <input type="checkbox"/> (2) Wet erase markers | <input type="checkbox"/> Measuring tape (300 cm) |
| <input type="checkbox"/> Picture of experimental set-up | <input type="checkbox"/> (4) Markers (orange, blue, green, purple) | <input type="checkbox"/> Large binder clip |
| <input type="checkbox"/> Lead lab coat | <input type="checkbox"/> Ruler | |

Notebook Page, Notepad Pages, and Picture Packet Page:

TECHNIQUE

Timers

Timers are used to measure an amount of time.

How to read a timer:
The diagram below shows what each number on a timer stands for

The above timer has gone for 1 hour, 12 minutes, 23 seconds and $\frac{7}{10}$ fraction of a second.

- If 3:00'45''³ is seen on your timer how much time has passed?
Hours: 3 Minutes: 0 Seconds: 45 Fraction of a Second: $\frac{3}{10}$
- If 0:01'07''² is seen on your timer how much time has passed?
Hours: 0 Minutes: 1 Seconds: 7 Fraction of a Second: $\frac{2}{10}$

How to use a timer:

- If timer is off, push the blue button to turn it on.
- If you do not see 0:00'00''⁰⁰⁰, push the blue button again to reset the timer.
- To start the timer, push the yellow button.
- To stop the timer, push the yellow button again.
- Record time to the nearest fraction of a second.
Example: 0:00'12''⁸ would be recorded as $12 \frac{8}{10}$ s.
- To reset to 0:00'00''⁰⁰⁰, push the blue button.
- Repeat.

Practice recording the amount of time it takes to do the following activities.

- How long does it take the SciTrek lead to unsnap/snap their lab coat? $2 \frac{2}{10}$ s
- How long does it take the SciTrek lead to jump three times? $1 \frac{5}{10}$ s

2

OBSERVATIONS

Experimental Set-Up:

- 2 ramps
 - o 1 shag carpet
 - o 1 outdoor carpet
- Plastic ball (green)
- Ball Circumference: 27 cm
- Ball Mass: 200 g
- Ramp Height: 13 cm
- Ramp Length: 50 cm
- Run Length: 100 cm
- Ruler
- Timer

1

OBSERVATIONS

Shag Carpet Run:

- Ball released from top of the ramp
- Time to hit the board: $1 \frac{5}{10}$ s, $1 \frac{6}{10}$ s, $1 \frac{7}{10}$ s
- Ball made a sound when it hit the board

Outdoor Carpet Run:

- Ball released from top of the ramp
- Time to hit the board: $1 \frac{1}{10}$ s, $1 \frac{0}{10}$ s, $1 \frac{2}{10}$ s
- Ball made a louder sound when it hit the board

2

Class Data Sheet

| Experiment | Shag Carpet (s) | Outdoor Carpet (s) |
|------------|------------------|--------------------|
| Lab | $1 \frac{5}{10}$ | $1 \frac{0}{10}$ |
| 1 | $1 \frac{7}{10}$ | $0 \frac{9}{10}$ |
| 2 | $1 \frac{9}{10}$ | $1 \frac{2}{10}$ |
| 3 | $1 \frac{6}{10}$ | $0 \frac{8}{10}$ |
| 4 | $1 \frac{4}{10}$ | $1 \frac{1}{10}$ |

Smallest \longrightarrow Largest

Shag Carpet (s)

| | | | | |
|------------------|------------------|------------------|------------------|------------------|
| $1 \frac{4}{10}$ | $1 \frac{5}{10}$ | $1 \frac{6}{10}$ | $1 \frac{7}{10}$ | $1 \frac{9}{10}$ |
| Minimum | | | | Maximum |

Outdoor Carpet (s)

| | | | | |
|------------------|------------------|------------------|------------------|------------------|
| $0 \frac{8}{10}$ | $0 \frac{9}{10}$ | $1 \frac{0}{10}$ | $1 \frac{1}{10}$ | $1 \frac{2}{10}$ |
| | | | | |

Page 1, Picture Packet

1

| VARIABLES | |
|--------------------|--|
| Variable | How will changing this variable affect ball motion? |
| Ball Mass | Heavier balls will hit the board first because they will gain more speed as they travel down the ramp. |
| Ramp Height | The taller the ramp height the faster the ball will hit the board because the ball will roll faster down the ramp. |
| Ball Circumference | The bigger the circumference the faster the ball will hit the board because larger objects gain more speed. |
| Ramp Length | The longer the ramp length the more time the ball will take to hit the board because it has a longer distance to travel. |
| Ball Material | Balls made out of rougher materials will take more time to hit the board because they will stick to the carpet more. |

3

Preparation:

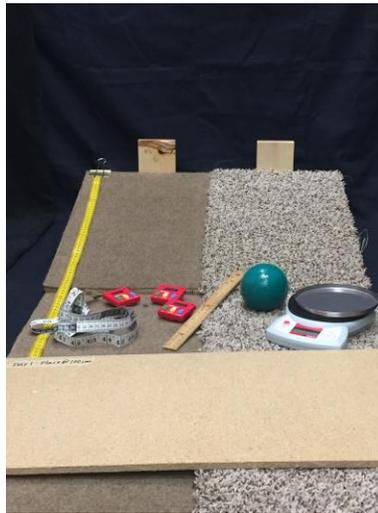
SciTrek Lead:

1. Make sure volunteers are writing their names and group colors on the whiteboard.
2. Make sure volunteers are passing out nametags.
3. Make sure volunteers are setting up for the initial observation. Details of how to do this are on a picture in the volunteer boxes.
4. Set up the document camera for the technique activity (page 2, notebook), and class data (page 1, picture packet).

SciTrek Volunteers:

1. On the front whiteboard in the classroom, write your name, and the color of the group (orange, blue, green, or purple) you will be working with.
2. Pass out nametags.
3. Assemble the experimental set-up (shown in picture below as well as in color in the experimental set-up picture in your group box) on a spot on the floor where approximately five students can sit.
 - a. Roll out the outdoor carpet.
 - b. Place the piece of shag carpet so that it covers half of the run.
 - c. Set up the outdoor carpet ramp in front of the outdoor carpet section of the run.
 - d. Set up the shag carpet ramp in front of the shag carpet section of the run.
 - e. Put the wood ramp holders under each of the ramps to give the ramps a slope.
 - f. Make sure the wood ramp holders are as far under the ramps as they can go.
 - g. Attach the 300 cm measuring tape (yellow) with the binder clip on the top of the shag carpet ramp and extend the measuring tape to the end of the run.
 - h. Set the ball stop board (65 cm x 30 cm) at the 100 cm mark on the measuring tape.

- i. Set the timers, 152 cm measuring tape (white), scale, ruler, and one of the green balls on the set-up.
 - j. Hide the second green ball in your lab coat pocket until the end of the observations.
4. Have notebooks and timers available to pass out.



Introduction:

(2 minutes – Full Class – SciTrek Lead)

For UCSB Lead:

“Hi, we are scientists from UCSB and we want to show you what we do as scientists. We will show you an experiment and then you can make observations, ask questions, and design your own experiment to help answer the class question. We want to show you that you can do science and have fun.”

For Teacher Lead:

“I have asked some scientists from UCSB to come and help us with a long-term science investigation. We will make observations, come up with a class question, and you will design your own experiment to help answer the class question.”

Allow the UCSB volunteers to introduce themselves and share their majors.

Question Assessment:

(5 minutes – Full Class – SciTrek Lead)

“Before we start with the module, we will determine how your ideas on testable questions are developing.” Have students write their name, teacher’s name, and date at the top of the assessment. Tell students, “When doing this assessment, you should work individually, so there should be no talking.” As you are giving the assessment, walk around the room, and verify students have written their names on their assessments.

Read the instructions aloud to students. Then, read each question and tell students, “Circle ‘testable’ for questions that science can answer or ‘not testable’ for questions that science cannot answer.” When they are finished, collect the assessments and verify the students’ names are on the papers.

Technique:

(10 minutes – Full Class – SciTrek Lead)

Have volunteers pass out a notebook to each student.

Have students fill out their name, teacher's name, group color (color of their name on their nametag: orange, blue, green, or purple), and their volunteer's name (volunteers' names should be written on the board next to the group color they will be working with) on the front cover of their notebooks. If a student does not have a nametag, only have them fill out their name and teacher's name on the cover of their notebook. They will be placed in a group when the class divides into groups for observations and they can fill out their group color and volunteer at that point.

Tell the class, "For this module, we are going to work together to try to answer the question, 'What variables affect ball motion?'" Ask students, "Why do you think scientists would investigate this question?" By the end of the conversation, make sure students understand if we can find patterns in ball motion, this means that motion is predictable, and we can predict future ball motion. Tell students, "In order to observe ball motion, we will need to be able to measure the time it takes a ball to travel a certain distance."

Have students turn to page 2 in their notebooks and place a class notebook under the document camera. Tell students, "For this experiment it is very important that your measurements of time are precise so we can tell exactly how long it takes the ball to hit a board at a given distance for each of your trials."

Go over how to read the timer using the diagram. Tell students, "The first number, before the colon, tells the number of hours for which the timer has run." Ask students, "How many hours did the top timer run?" Students should reply, "1 hour." Tell students, "The next number, between the colon and the apostrophe, is the number of minutes for which the timer has run." Ask students, "How many minutes did the top timer run?" Students should reply, "12 minutes." Tell students, "The next number, between the apostrophe and the quote, is the number of seconds for which the timer has run." Ask students, "How many seconds did the top timer run?" Students should reply, "23 seconds." Tell students, "The last number (the small number) shows the parts of seconds." Ask students "Do we know a way to record numbers that are a part of a whole?" Possible student response: we can record parts of whole numbers using fractions. Have students identify that the parts of a second go up to 9 and then restart counting at 0. Ask students, "What should the bottom number, or the denominator, be for this fraction?" Students should reply, "The denominator will be 10." Tell students, "The numerator, or top number of the fraction, will be the small number we see on our timer." Ask students, "How should we record the parts of seconds for the top timer?" Possible student response: the 7 parts on the timer should be put into a fraction over 10, giving $\frac{7}{10}$. Tell students, "You will now fill out questions 1 and 2 on their own." Once students are done go over the answers as a class.

TECHNIQUE
Timers

Timers are used to measure an amount of time.

How to read a timer:
The diagram below shows what each number on a timer stands for

The above timer has gone for 1 hour, 12 minutes, 23 seconds and $\frac{7}{10}$ fraction of a second.

- If 3:00'45"³ is seen on your timer how much time has passed?
Hours: 3 Minutes: 0 Seconds: 45 Fraction of a Second: $\frac{3}{10}$
- If 0:01'07"² is seen on your timer how much time has passed?
Hours: 0 Minutes: 1 Seconds: 7 Fraction of a Second: $\frac{2}{10}$

How to use a timer:

- If timer is off, push the blue button to turn it on.
- If you do not see 0:00'00"⁰⁰, push the blue button again to reset the timer.
- To start the timer, push the yellow button.
- To stop the timer, push the yellow button again.
- Record time to the nearest fraction of a second.
Example: 0:00'12"⁸ would be recorded as $12\frac{8}{10}$ s.
- To reset to 0:00'00"⁰⁰, push the blue button.
- Repeat.



Practice recording the amount of time it takes to do the following activities.

- How long does it take the SciTrek lead to unsnap/snap their lab coat? $2\frac{2}{10}$ s
- How long does it take the SciTrek lead to jump three times? $1\frac{5}{10}$ s

2

Have students go through questions 1 and 2 on their own. Walk around to help the students who are struggling. After approximately two minutes, bring the class back together to go over the answers.

Go over the answers for questions 1 and 2. Have a student tell you their answer and have the class compare their own answers using thumbs up/thumbs down. After the class agrees on the correct answer, record it in the class notebook.

Tell students, "Now that you know how to read a timer, you must also learn how to operate a timer." Go through the steps listed in their notebook. While you are going through the steps, have the SciTrek volunteers pass out a timer to each student.

- If the timer is off, push the blue button to turn it on.
- If you do not see 0:00'00"⁰⁰, push the blue button again to reset the timer.
- To start the timer, push the yellow button.
- To stop the timer, push the yellow button again.
- Record the time to the nearest tenth of a second. Example: 0:00'12"⁸ would be recorded as $12\frac{8}{10}$ s.
- To reset to 0:00'00"⁰⁰, push the blue button.
- Repeat.

Let students practice starting, stopping, and clearing the timer.

Tell students, "You are now going to time two different activities. For the first activity, you will record the amount of time it takes me to unsnap and snap my lab coat." Have a volunteer time the processes with the students so students have a number to compare their time to. Count down to the start by saying "3...2...1...Go." Students should start their timers when you say go. They should stop their timer when the last snap is done. Try to make this take approximately 15 seconds. Have each student write down the time they recorded in their own notebook. Have students check their time with the volunteer's time. Students should be able to get within one second of the volunteer's time.

Tell students, “For the second activity, you will record how long it takes me to jump three times. I am a good jumper so this will go very quickly, and you need to pay close attention. You will start timing when I say go and stop timing when my feet hit the ground on the third jump.” Ask students, “If you cannot see my feet hit the ground when I am jumping, will you still be able to tell when I have hit the ground after my third jump?” Possible student response: yes, we will be able to hear your feet hit the ground. Make sure that all students and a volunteer have reset their timers using the blue button. Remind students that the yellow button is used to start and stop the timer. Count them down to the start by saying “3...2...1...Go.” On go, start jumping. Have each student write down the time they recorded in their own notebook. Have students check their time with the volunteer’s time. Students should be able to get within $\frac{4}{10}$ of a second of the volunteer’s time.

Tell students, “Now you know how to use a timer, you will be able to use this skill to help you make observations.”

Observation Discussion:

(2 minutes – Full Class – SciTrek Lead)

Tell students, “Scientists make many observations.” Ask students, “What is an observation? What are the types of things you can record for an observation?” If they have trouble, show them an object, and let them make observations. Turn these specific observations into general features of an observation. Examples of possible general observations are: color, texture, size, weight, temperature, etc. Help them realize, an observation is a description using your five senses.

Tell students, “In this experiment we are going to make observations of a ball rolling down two runs made out of different materials. These observations will help us determine if run materials affect ball motion.”

Tell the class, “You will now get in your groups, and make observations. To determine your group, you will need to look at the color of your nametag (orange, blue, green or purple).” Tell each colored group where to go and to bring their timer and notebook.

If a student does not have a nametag, identify the group color with the least number of students in it, and write the student’s name on one of the extra nametags, in the lead box, using that color of marker.

Observations:

(15 minutes – Groups – SciTrek Volunteers)

Once students come over to your group, have them sit in boy/girl fashion, collect their timers and notebooks, and put them in your group box. Students will not need their notebooks until the next session. Put out three timers and verify that the floor is set up as described in the Set-Up Section.

As a group, have students generate observations about the experimental set-up before you roll the ball down the ramp. This should take you no longer than 10 minutes. Observations should be recorded on page 1 of the notepad. Make sure to record the following observations about the experimental set-up: ramp height (13 cm), ramp length (50 cm), the run distance (distance to the ball stop board) (100 cm), ball mass (~200 g), and ball circumference (27 cm). Use the scale to measure the mass of the ball.

Pass out a timer to three students. **Make sure only 3 students are timing and you only do the trial once.** Tell the other students, “You will get a chance to measure the time the ball takes to hit the board for the next trial.” Put the ball at the top of the shag carpet ramp, against the ramp holder. Tell students, “You will stop the timer when you both see and hear the ball hit the board.” Count down by saying

“3...2...1...Go” and release the ball. On the notepad, record the three times students measured as well as other observations about the shag carpet. Remember to record the partial seconds in a fraction of 10. Do not have students find the median of the time. This should take no longer than 2 minutes.

Repeat the process for the outdoor carpet ramp, having three different students time. Put the ball at the top of the ramp and count down by saying “3...2...1...Go,” and release the ball. Again, on the group notepad, record the three times to the nearest tenth of a second in fraction form, as well as other observations about the outdoor carpet. This should take no longer than 2 minutes.

Ask students, “What was different about the two runs?” Possible student response: it took the ball longer to hit the board with shag carpet than outdoor carpet. Ask students, “Is there another way that we could prove that the ball takes longer to reach the board when the ball is rolled on shag carpet instead of outdoor carpet?” Make sure by the end of the conversation that students generate the idea of racing two balls: one on the shag carpet ramp and one on the outdoor carpet ramp. Once students have generated this idea, bring out the other green ball. Place both balls at the top of the ramp and release them at the same time.

The lead will come around to write down each group’s data on the class data sheet (page 1, picture packet). Lead note: even though each group is writing down three times and they will not have determined the median only write the median time on the class data sheet.

If there is additional time, have students summarize what they saw and learned. Make sure students know for this experiment their changing variable was run material and how run material affected ball motion.

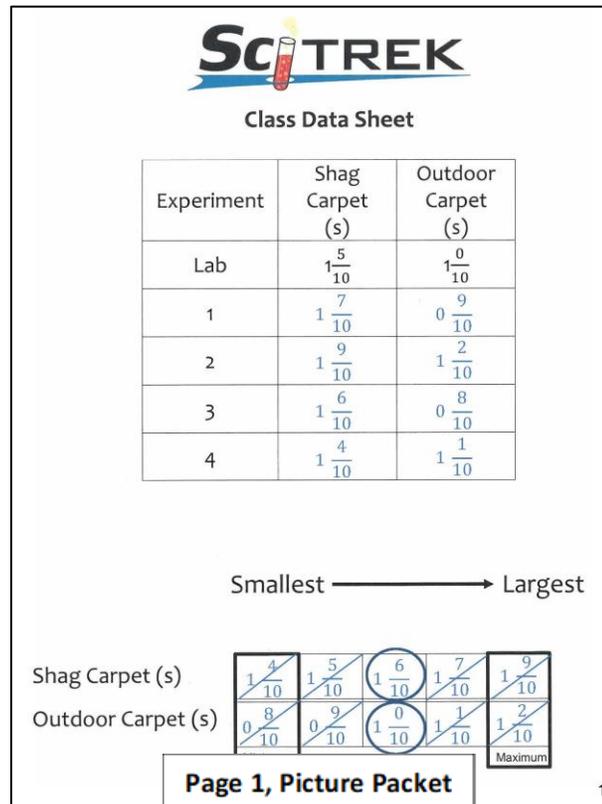
An example filled out initial observations is shown below.

| OBSERVATIONS | OBSERVATIONS |
|---|---|
| <p>Experimental Set-Up:</p> <ul style="list-style-type: none"> • 2 ramps <ul style="list-style-type: none"> ◦ 1 shag carpet ◦ 1 outdoor carpet • Plastic ball (green) • Ball Circumference: 27 cm • Ball Mass: 200 g • Ramp Height: 13 cm • Ramp Length: 50 cm • Run Length: 100 cm • Ruler • Timer <p style="text-align: right;">1</p> | <p>Shag Carpet Run:</p> <ul style="list-style-type: none"> • Ball released from top of the ramp • Time to hit the board: $1\frac{5}{10}$ s, $1\frac{6}{10}$ s, $1\frac{7}{10}$ s • Ball made a sound when it hit the board <p>Outdoor Carpet Run:</p> <ul style="list-style-type: none"> • Ball released from top of the ramp • Time to hit the board: $1\frac{1}{10}$ s, $1\frac{0}{10}$ s, $1\frac{2}{10}$ s • Ball made a louder sound when it hit the board <p style="text-align: right;">2</p> |

Reproducibility Discussion:

(8 minutes – Full Class – SciTrek Lead)

Have students look at the class data sheet (page 1, picture packet) seen below. Ask students, “Did every group get the same results?” They should reply, “No.” Ask students, “Did all of the groups run the same experiment?” Have students explain the experiment they carried out, as well as what they measured in their groups. They should all realize that they did the same experiment. Ask students, “Why did groups get different times if they all did the same experiment?” Possible student responses: the ball did not roll straight, a ball wasn’t released from exactly the top of the ramp, or different students might have stopped the timer at different times.



Tell students, “Scientists often perform multiple trials of the same experiment to try to account for any error or inconsistency in their data. However, when they present their data, they like to report one number instead of all the numbers they measured.”

Ask the class, “What number would you pick if you had to pick one data point to represent the time it took the ball to hit the board on both outdoor and shag carpet?” Since students used the median number for representing an entire data set in their last SciTrek module, they will most likely give this example.

Tell students, “You are going to find the median number in each set of numbers.” Starting with the run on shag carpet, have students rearrange the numbers so that they are in increasing order. Then, have students identify the middle number. With both the lab data and the students’ data, there should be five numbers, which will give one middle number. Repeat this process for the trial on the outdoor carpet.

Ask students, “What did you learn about ball motion from this experiment?” Students should be able to tell you the run material affects ball motion and the smoother the surface, the shorter the time it takes for the ball to hit the board (faster the ball travels). Ask students, “Can you predict one surface that would cause the ball to hit the board in a shorter time than outdoor carpet and one surface that would cause a

longer time than shag carpet?" Possible student response: smooth plastic would cause a shorter time than outdoor carpet and long grass would cause a longer time than shag carpet.

Variable Discussion:

(2 minutes – Full Class – SciTrek Lead)

Tell students they are now going to think about other variables they could test to help them better understand ball motion.

Lead students through the following questions, and explanations:

What does the word 'variable' mean to a scientist?

(variables are the parts of the experiment that you can change)

What was the changing variable in the experiment that we just did?

(ramp material)

Do you think there are multiple variables that will affect ball motion?

(multiple variables might affect ball motion)

Explain, this is why we will need to work as a class to answer the class question: "What variables affect ball motion?"

Tell the class, "You are going to think about variables, in the experiment, you could change, to help us answer the class question. In addition to generating variables, you should think about, how, and/or why, these variables might affect the outcome of the experiment." Ask the class, "What do you think is a variable that might affect the ball motion?" Then, have them tell you how, and why, they think that variable would affect ball motion. Probe them on how they would design an experiment to test whether this variable affected the ball motion. Finally, have the students make a prediction of the results for the experiment they proposed. Remind students, "Predictions can be wrong, and we will not know the true answers until we carry out the experiment."

Ex: *Variable:* ramp height

Why might this variable affect ball motion? Higher ramps might cause the ball to move faster down the ramp and hit the board in less time.

How would you test this variable? Do several trials in which you release the ball from multiple different ramp heights.

Prediction: The taller the ramp the shorter the time for the ball to hit the board.

Tell students, "You will now generate more variables, and analyze them in your groups."

Variables:

(13 minutes – Groups – SciTrek Volunteers)

As a group, generate a variable, and make a prediction about how it will affect ball motion. Encourage, and challenge, students to explain why they think their prediction is correct, and how this variable will affect ball motion. Record both the variable and the prediction on the notepad. After each prediction, survey your group and write down how many students agree with the prediction and how many disagree. If there is extra time, go around the table a second time. An example filled out variables is shown below. Students do not need to record the variables or predictions in their notebooks.

Prepare one student to share a variable, and why they think it will affect ball motion, during the class discussion.

| VARIABLES | |
|--------------------|--|
| Variable | How will changing this variable affect ball motion? |
| Ball Mass | Heavier balls will hit the board first because they will gain more speed as they travel down the ramp. |
| Ramp Height | The taller the ramp height the faster the ball will hit the board because the ball will roll faster down the ramp. |
| Ball Circumference | The bigger the circumference the faster the ball will hit the board because larger objects gain more speed. |
| Ramp Length | The longer the ramp length the more time the ball will take to hit the board because it has a longer distance to travel. |
| Ball Material | Balls made out of rougher materials will take more time to hit the board because they will stick to the carpet more. |

3

Wrap-Up:

(3 minutes – Full Class – SciTrek Lead)

Have one student from each group share a variable they generated and how, and, why they think it will affect ball motion. Make sure, students tell you their predictions about how different values of that variable will affect ball motion.

Tell students, “Next session, you will design an experiment to answer the class question: What variables affect ball motion?, which will help you learn about ball motion.”

Clean-Up:

1. Collect notebooks with attached nametags.
2. Place ramps and runs in the appropriate bags.
3. Place all other materials in your group box, and bring them back to UCSB.

Day 2: Question Activity/Questions/Materials Page/Experimental Set-Up

Schedule:

- Introduction (SciTrek Lead) – 2 minutes
- Question Activity (SciTrek Lead) – 20 minutes
- Question Discussion (SciTrek Lead) – 3 minutes
- Testable Questions (SciTrek Volunteers) – 8 minutes
- Question Discussion (SciTrek Lead) – 3 minutes
- Non-Testable Questions (SciTrek Volunteers) – 4 minutes
- Question/Experimental Set-Up Discussion (SciTrek Lead) – 3 minutes
- Question (SciTrek Volunteers) – 4 minutes
- Materials Page (SciTrek Volunteers) – 5 minutes
- Experimental Set-Up (SciTrek Volunteers) – 5 minutes
- Wrap-Up (SciTrek Lead) – 3 minutes

Materials:

(4) Volunteer Boxes:

- | | | |
|---|---|---|
| <input type="checkbox"/> Nametags | <input type="checkbox"/> Volunteer lab coat | <input type="checkbox"/> (2) Pencils |
| <input type="checkbox"/> Notebooks | <input type="checkbox"/> (5) Materials pages (one for each possible variable) | <input type="checkbox"/> (2) Grease pencils |
| <input type="checkbox"/> Volunteer instructions | | |

Other Supplies:

- | | | |
|---------------------------------------|--|--|
| <input type="checkbox"/> (4) Notepads | <input type="checkbox"/> Board (45cm × 30cm) with outdoor carpet | <input type="checkbox"/> Board (60cm × 30cm) with outdoor carpet |
|---------------------------------------|--|--|

Lead Box:

- | | | |
|---|---|--|
| <input type="checkbox"/> (3) Blank nametags | <input type="checkbox"/> Time card | <input type="checkbox"/> Purple ball (27 cm circ., ~360 g) |
| <input type="checkbox"/> (3) Extra notebooks | <input type="checkbox"/> (2) Pencils | <input type="checkbox"/> Red ball (27 cm circ., ~55 g) |
| <input type="checkbox"/> Lead instructions | <input type="checkbox"/> (2) Wet erase markers | <input type="checkbox"/> Green ball (30 cm circ., ~200 g) |
| <input type="checkbox"/> Motion picture packet | <input type="checkbox"/> (4) Marker (orange, blue, green, purple) | <input type="checkbox"/> Green ball (21 cm circ., ~200 g) |
| <input type="checkbox"/> Lead lab coat | | |
| <input type="checkbox"/> (5) Materials pages (one for each possible variable) | | |

Notebook Pages, and Notepad Pages:

SCIENTIFIC PRACTICE
Questions

Circle TESTABLE if the question can be tested by science. Circle NOT TESTABLE if the question cannot be tested by science.



1. How much does an astronaut's suit weigh? Testable Not Testable
2. Do dogs like Astronaut Ice Cream? Testable Not Testable
3. Is Venus prettier than Saturn? Testable Not Testable
4. How many moons orbit Jupiter? Testable Not Testable
5. Which planet, other than Earth, is the most habitable? Testable Not Testable
6. How fast does Luke Skywalker fly his spaceship? Testable Not Testable
7. How many telescopes are there in the United States? Testable Not Testable
8. Is the space shuttle big? Testable Not Testable
9. Is studying the solar system valuable? Testable Not Testable
10. What color light do stars give off? Testable Not Testable

Circles are your initial thought and boxes are the correct answer.

3

SCIENTIFIC QUESTIONS

If we change the ball mass,
what will happen to the time it takes to hit the board?

- If the ball circumference is changed, how long will it take the ball to hit the board?
- How long will it take the ball to hit the board, if we change the ramp height?

4

NON-SCIENTIFIC QUESTIONS

- Does the ball like rolling down the ramp?
- How fast can Tinkerbelle go down the ramp?
- Is the ramp big?
- What kind of ball is better, a big one or a small one?

5

Changing Variable: Ball Mass

Why do you think your changing variable will affect ball motion?

The heavy balls will take less time to hit the board because the heavier ball will pick up more speed.

QUESTION

Question our group will investigate:

- If we change the ball mass, what will happen to the time the ball takes to hit the board?

Changing Ball Mass Color: blue

You will only have access to the following materials.

General Materials (check all that apply)

(3) Timers Ball stop board Ruler

Scale 300 cm measuring tape 151 cm measuring tape

Run Material (check 1)

Outdoor Carpet (original)

Run Length (select 1) Select a run length between 50 cm and 200 cm.

Run length we will use: 200 cm

Ramp Height (check 1)

15 cm (original) 22 cm

Ramp Length (check 1)

50 cm (original)

Ball Circumference (check 1)

27 cm (original)

Ball Mass (check 4 and write the trail letter after each value selected)

~55 g C ~100 g ~165 g B ~305 g (original)

~265 g A ~305 g ~360 g D

6

Experimental Considerations:

1. You will only have access to the materials on the materials page.
2. You will run four trials.
3. For each trial you must measure the time the ball travels (time from ball release to ball hitting the board) three times.

Changing Variable (Independent Variable): Ball mass

Discuss with your group how you think your changing variable will affect ball motion.

QUESTION

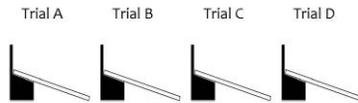
Question our group will investigate:

- If we change the ball mass, what will happen to the time the ball takes to hit the board?

Fill out the materials page with your SciTrek volunteer before moving onto the experimental set-up.

4

EXPERIMENTAL SET-UP



Changing Variable:

Ball Mass : ~265 g ~165 g ~55 g ~360 g

Controls (variables you will hold constant):

Object Type / Ball Ramp Length / 50 cm

Ball Circumference / 27 cm Run Material / Outdoor Carpet

Ramp Height / 22 cm Run length / 200 cm

Predictions:

I predict when the ball mass is _____ the ball will hit the board in the least amount of time.

I predict when the ball mass is _____ the ball will hit the board in the most amount of time.

7

EXPERIMENTAL SET-UP

Write your changing variable (Ex: ball mass) and the values (Ex: 15 g) you will use for your trials under each set-up.



Changing Variable:

Ball Mass : ~265 g ~165 g ~55 g ~360 g

Controls (variables you will hold constant):

Write your controls and the values you will use in all your trials (control/value, Ex: object type/ball).

Object Type / Ball Ramp Length / 50 cm

Ball Circumference / 27 cm Run Material / Outdoor Carpet

Ramp Height / 22 cm Run Length / 200 cm

Predictions

I predict that when the ball mass is _____ the ball will hit the board in the least amount of time.

I predict that when the ball mass is _____ the ball will hit the board in the most amount of time.

5

Preparation:

SciTrek Lead:

1. Make sure volunteers are setting out notebooks.
2. Set up the document camera for the question activity (page 3, notebook).

SciTrek Volunteers:

1. Set out notebooks/nametags.

Note: Set notebooks where students will sit during the module, even if another student is currently at that desk. If needed, students will move to these spots after the Introduction.

Introduction:

(2 minutes – Full Class – SciTrek Lead)

If students are not in their groups, tell them, “A notebook will be put on your desk, which is not your notebook and you should not move it. You will move to your notebook after the Introduction.

Ask students, “What did we do and learn during our last meeting?” Possible student response: we did an experiment in which we changed the run material and timed how long it took a ball to roll down two different runs and hit a board. One run was made from outdoor carpet and one was made from shag carpet. We learned that the outdoor carpet (which was smoother) caused the ball to hit the board in less time than the shag carpet. Ask the class, “What is the class question we will be investigating?” Students should reply, “What variables affect ball motion?”

Ask students, “Why might scientists study ball motion?” Students should explain that studying ball motion will help them predict what will happen to an object that is in motion. For instance, the first experiment showed that the ball took less time to hit the board on a smooth surface than on a bumpy surface, which suggests that other objects in motion will travel faster on smooth surfaces than on bumpy surfaces.

Tell students, “One-way scientists answer questions is by performing experiments; today you are going to generate testable questions about the ramp set-up. After, you will be able to pick a question and design an experiment to answer that question. First, we are going to look at a list of questions and decide whether each question is testable by science.”

Question Activity:

(20 minutes – Full Class – SciTrek Lead)

Ask students, “What type of questions can be tested by science?” You should get answers that revolve around the idea that science can test things that are measurable, observable, or countable. Write on the board:

Testable Questions:

- Measurable
- Observable
- Countable

Ask students, “What type of questions cannot be tested by science?” You should get the following two groups of untestable questions:

- 1) Questions in which the data cannot be acquired.
 - Data cannot be acquired on objects or characters that do not exist. Ex: How many fingers do fairies have? Since we cannot catch fairies, we would not be able to answer this question.

2) Questions that are not well defined or are opinions.

- Opinion questions contain opinion words such as prettier, nicest, better, etc. Ex: Which are prettier, lilies or daisies?
- Not well defined questions contain words such as affected, react, etc. Ex: Do squirrels react to dogs?
- Not well defined questions can contain semi-measurable words such as big, wide, heavy, etc. Ex: Is the Golden Gate Bridge wide? The problem with this question is you do not know how the questioner defines the word wide. A scientist could answer this question “yes” if they were comparing the Golden Gate Bridge to a typical overpass bridge while another scientist could answer the question “no” because they were comparing the Golden Gate Bridge to the Pacific Ocean.

Write on the board:

Not Testable Questions:

Can't acquire data

Not well defined/Opinion

Have student turn to page 3 of their notebooks, and place page 3 of the class notebook under the document camera. Read the directions aloud to the class. Read the first question to students, then give them approximately 15 seconds to circle the answer. Have a student share whether they think the question is testable or not. Then, have the class vote using thumbs up/thumbs down if they agree/disagree with the student's reasoning. After the class has come to a consensus, tell students, “We will now box the correct answer. Even if you got the answer wrong you should not erase your original answer because this will let you see which concepts/categories you are struggling with.” Box the correct answer on the class notebook for students to copy.

For questions that are testable, have students tell you what they would measure/count/observe to answer the question. Write the type of data they would collect in the margins of the class notebook. For questions that are not testable, have the students identify why the statement is not testable (can't acquire data/not well defined) and if applicable, underline the non-testable word in the question. Write why the question is not testable in the margins of the class notebook. Then, have the students propose a related question that is testable.

SCIENTIFIC PRACTICE
Questions

Circle TESTABLE if the question can be tested by science. Circle NOT TESTABLE if the question cannot be tested by science.



| | | | |
|---|--|--|---------------------------|
| 1. How much does an astronaut's suit weigh? | <input checked="" type="checkbox"/> Testable | <input type="checkbox"/> Not Testable | <i>Measure</i> |
| 2. Do dogs <u>like</u> Astronaut Ice Cream? | <input type="checkbox"/> Testable | <input checked="" type="checkbox"/> Not Testable | <i>Not well defined</i> |
| 3. Is Venus <u>prettier</u> than Saturn? | <input type="checkbox"/> Testable | <input checked="" type="checkbox"/> Not Testable | <i>Not well defined</i> |
| 4. How many moons orbit Jupiter? | <input checked="" type="checkbox"/> Testable | <input type="checkbox"/> Not Testable | <i>Count</i> |
| 5. Which planet, other than Earth, is the most <u>habitable</u> ? | <input type="checkbox"/> Testable | <input checked="" type="checkbox"/> Not Testable | <i>Not well defined</i> |
| 6. How fast does <u>Luke Skywalker</u> fly his spaceship? | <input type="checkbox"/> Testable | <input checked="" type="checkbox"/> Not Testable | <i>Can't Acquire Data</i> |
| 7. How many telescopes are there in the United States? | <input checked="" type="checkbox"/> Testable | <input type="checkbox"/> Not Testable | <i>Count</i> |
| 8. Is the space shuttle big? | <input type="checkbox"/> Testable | <input checked="" type="checkbox"/> Not Testable | <i>Not well defined</i> |
| 9. Is studying the solar system <u>valuable</u> ? | <input type="checkbox"/> Testable | <input checked="" type="checkbox"/> Not Testable | <i>Not well defined</i> |
| 10. What color light do stars give off? | <input checked="" type="checkbox"/> Testable | <input type="checkbox"/> Not Testable | <i>Observe</i> |

Circles are your initial thought and boxes are the correct answer.

3

Below are the answers to 1-10 on page 3 in detail.

1: How much does an astronaut's suit weigh?

Is this question testable?

Yes.

What could be measured/observed to answer this question?

Measure the weight of an astronaut's suit.

2: Do dogs like Astronaut Ice Cream?

Is this question testable?

No.

Why is the question not testable?

The word "like" is an opinion and it is impossible to measure if a dog *likes* Astronaut Ice Cream. (A dog could eat the Astronaut Ice Cream because it likes the ice cream or because it is hungry and needs nutrients.)

How can we revise this question to make it testable?

Which food do dogs eat first, Astronaut Ice Cream or steak?

3: Is Venus prettier than Saturn?

Is this question testable?

No.

Why is the question not testable?

The word "prettier" is not well defined/opinion. Many people disagree about which objects are prettier.

How can we revise this question to make it testable?

Which planet has more rings, Venus or Saturn?

4: How many moons orbit Jupiter?

Is this question testable?

Yes.

What could be measured/observed to answer this question?

Count the number of moons that orbit Jupiter.

5: Which planet, other than Earth, is the most habitable?

Is this question testable?

No.

Why is the question not testable?

The word "habitable" is not well defined/opinion. (Habitable could mean that the planet has water or could mean that the planet has the same temperature range as Earth.)

How can we revise this question to make it testable?

What is the hottest temperature recorded on Venus in 2012?

6: How fast does Luke Skywalker fly his spaceship?

Is this question testable?

No.

Why is the question not testable?

We will not be able to acquire data on Luke Skywalker because he is a fictional character.

How can we revise this question to make it testable?

What is the speed of an average space shuttle?

7: How many telescopes are there in the United States?

Is this question testable?

Yes. (Even though this question is hard to test, it still can be tested.)

What could be measured/observed to answer this question?

Count the number of telescopes in the United States.

8: Is the space shuttle big?

Is this question testable?

No.

Why is the question not testable?

The word "big" is not well defined in this context. (The space shuttle is big compared to people, but small compared to the Earth.)

How can we revise this question to make it testable?

Which is taller, the space shuttle or a person? or What is the size of the space shuttle?

9: Is studying the solar system valuable?

Is this question testable?

No.

Why is the question not testable?

The word "valuable" is not well defined/opinion. (Valuable could mean that studying the solar system can increase their knowledge about space or could mean that you could use this knowledge to make money.) Note: this question is particularly hard for students because they think the answer to the question is yes. Instead of thinking about if the question is testable or not, they try to argue the answer is "yes."

How can we revise this question to make it testable?

Does studying the solar system increase the number of planets people can name?

10: What color light do stars give off?

Is this question testable?

Yes.

What could be measured/observed to answer this question?

Observe stars and determine the color light they give off.

Question Discussion:

(3 minutes – Full Class – SciTrek Lead)

Tell students, “You are now going to generate your own testable questions about the ramp set-up you used last session. You will be able to use the variables you generated last time to help you with your questions.” Make sure students understand scientists define a variable as something that can be changed in an experiment to learn something about the system. Have a few students share variables that they generated last class session.

Hold up one of the group notepads with the following sentence frame:

If we change the _____, what will happen to the _____?

variable what you are measuring/observing

Tell students, “You can insert a variable into blank one and something you can measure/observe into blank two to generate a testable question.”

As a class, come up with one question that fits this sentence frame.

Ex: “If we change the ramp height, what will happen to the time it takes the ball to hit the board?”

Tell students, “You will now work together to generate as many testable questions about the ramp set-up as possible.”

Testable Questions:

(8 minutes – Groups – SciTrek Volunteers)

As a group, have the students generate a question in the form: “If we change the _____, what will happen to the _____?” After they have generated one question in this form, they may generate other questions in any form they want. If students do not generate testable questions in the form provided, try to have students identify what data they would need to collect to answer their question. Ex: What is the longest ramp in the world? The data that would need to be collected is the measurements of the lengths of all the ramps in the world. If students are having trouble generating questions, have them review the variables that they generated during the previous meeting.

Prepare one student to share a question with the class. An example filled out scientific questions is shown below.

SCIENTIFIC QUESTIONS

If we change the ball mass,
 what will happen to the time it takes to hit the board?

- If the ball circumference is changed, how long will it take the ball to hit the board?
- How long will it take the ball to hit the board, if we change the ramp height?

4

NON-SCIENTIFIC QUESTIONS

- Does the ball like rolling down the ramp?
- How fast can Tinkerbelle go down the ramp?
- Is the ramp big?
- What kind of ball is better, a big one or a small one?

5

Question Discussion:

(3 minutes – Full Class – SciTrek Lead)

Have one student from each group share one of their testable questions with the class. After a group's question is presented, ask the rest of the class, "Is the question testable, and, if so, what data would the group need to collect to answer the question?"

Tell students, "There are many questions that science cannot answer." Ask students, "Do you know the types of questions science cannot answer?" They should be able to generate the following two categories of questions:

Category 1: Can't acquire data

Category 2: Not well defined/opinion

Ask students, "Can someone give an example question about the ramp set-up that science cannot answer?"

Ex: Category 1 Question: Does the ball roll down the ramp at the same speed in Neverland?

Ex: Category 2 Questions: Does the ball like rolling down the ramp? or Is learning about ball motion important?

Tell students, "You are now going to generate questions that science cannot answer about the ramp set-up with your group."

Non-Testable Questions:

(4 minutes – Groups – SciTrek Volunteers)

Have students generate a list of questions that science cannot answer and record them on the notepad. Encourage students to generate questions that are in both of the non-testable categories. If they are struggling, have them turn to the question activity and look at the questions that are not testable. Ask students, “Why is this question not testable?” Then have them use it as a model to generate a question about the ramp set-up.

Prepare one student to share one of their questions with the class. An example filled out non-scientific questions is shown above.

Question/Experimental Set-Up Discussion:

(3 minutes – Full Class – SciTrek Lead)

Have each group share one question that they generated that science cannot answer. After a group’s question is presented, ask the rest of the class, “Is the question testable and, if not, why?”

Tell students, “You are going to design an experiment to determine how one variable affects ball motion. First, you will pick a changing variable and record it in your notebooks. Your options for your changing variable are ramp height, ramp length, ball mass, ball circumference, and run length.” Show students the example materials as they are being discussed. Tell students, “Second, you will discuss why you think this variable will affect ball motion and determine your experimental question. Third, you will use the materials page to determine the values of your changing variable and controls. Fourth, you will determine your experimental set-up.” Ask students, “How do scientists define controls?” By the end of the conversation make sure students understand that controls are variables that could have changed but are kept constant for their experiment. Go over the experimental considerations with students (page 4, notebook).

Experimental Considerations:

1. You will only have access to the materials on the materials page.
2. You will run four trials.
3. For each trial you must measure the time the ball travels (time from ball release to ball hitting the board) three times.

Question:

(4 minutes – Groups – SciTrek Volunteers)

Have students turn to page 4 of their notebooks. Then, have your group decide (by voting) what changing variable they want to explore for their experiment. If there is a tie, then the volunteer will make the deciding vote. It is best if groups have different changing variables. The lead will help coordinate between groups to ensure there is a variety of changing variables.

As a group, discuss why/how they think their changing variable will affect ball motion. Record their thoughts on the notepad; students will not write this in their notebooks.

Use their changing variable to generate the question that the group is going to investigate. Write the question in the group notepad, and have students copy it into their notebooks. An example filled out question is shown below.

Select a student to read the group question during the wrap-up.

Changing Variable: Ball Mass

Why do you think your changing variable will affect ball motion?
The heavy balls will take less time to hit the board because the heavier ball will pick up more speed.

QUESTION

Question our group will investigate:

- If we change the ball mass, what will happen to the time the ball takes to hit the board?

Color: blue

Changing Ball Mass
 You will only have access to the following materials.
 General Materials (check all that apply)
 (1) Timers Ball stop board Ruler
 Scale 300 cm measuring tape 151 cm measuring tape
 Run Materials (check 1)
 Outdoor Carpet (original)
 Run Length (select 1) Select a run length between 50 cm and 200 cm.
 Run length we will use: 200 cm
 Ramp Height (check 1)
 11 cm (original) 22 cm
 Ramp Length (check 1)
 50 cm (original)
 Ball Circumference (check 1)
 27 cm (original)
 Ball Mass (check 4 and write the trail letter after each value selected)
 -55 g C -100 g -165 g B -205 g (original)
 -195 g A -305 g -316 g D

6

Experimental Considerations:

1. You will only have access to the materials on the materials page.
2. You will run four trials.
3. For each trial you must measure the time the ball travels (time from ball release to ball hitting the board) three times.

Changing Variable (Independent Variable): Ball mass

Discuss with your group how you think your changing variable will affect ball motion.

QUESTION

Question our group will investigate:

- If we change the ball mass, what will happen to the time the ball takes to hit the board?

Fill out the materials page with your SciTrek volunteer before moving onto the experimental set-up.

4

Materials Page:

(5 minutes – Groups – SciTrek Volunteers)

Get the materials page (shown below) that corresponds to the changing variable that your group selected, and tape it into the notepad. Have students use the materials page to choose the values of their controls and changing variable.

When selecting the values of the changing variable, ask students, “Do you think a wide or a narrow range of values would help you more effectively answer your question?” Make sure they understand that a wide

range of values will make it easier for them to see a difference in their results, and thus have a better understanding of the answer to the class question. For each changing variable value, write the trial letter (A, B, C, D) next to the value.

For controls in which students can pick more than one value (run length, ramp height, and ball mass), have students discuss if the value that they select for their control would make it easier or harder to answer their question. For example, if students chose a run length of 50 cm, ask them, “How do you think having a run length of 50 cm would affect the experiment?” This might get them to realize that a 50 cm run would have a very short time, resulting in most of the times being approximately the same for all of the trials. If they decide a different control value is better, allow them to switch control values.

Make sure that your group checked off all of the materials that they will need from the materials page and that your group color is written on the top of the page. Make sure that students have picked run lengths/ramp heights that are within the limitations set on the materials page. Examples of all materials pages are shown below.

| | |
|---|---|
| <p style="text-align: right;">Color: _____</p> <p>Changing Ball Mass You will only have access to the following materials.</p> <p>General Materials: (check all that apply)</p> <p><input type="checkbox"/> (3) Timers <input type="checkbox"/> Ball stop board <input type="checkbox"/> Ruler <input type="checkbox"/> Scale <input type="checkbox"/> 300 cm measuring tape <input type="checkbox"/> 152 cm measuring tape</p> <p>Run Material: (check 1) <input type="checkbox"/> Outdoor Carpet (original)</p> <p>Run Length: (select 1) Select a run length between 50 cm and 200 cm. Run length we will use: _____</p> <p>Ramp Height: (check 1) <input type="checkbox"/> 13 cm (original) <input type="checkbox"/> 22 cm</p> <p>Ramp Length: (check 1) <input type="checkbox"/> 50 cm (original)</p> <p>Ball Circumference: (check 1) <input type="checkbox"/> 27 cm (original)</p> <p>Ball Mass: (check 4 and write the trail letter after each value selected)</p> <p><input type="checkbox"/> -55 g <input type="checkbox"/> -100 g <input type="checkbox"/> -165 g <input type="checkbox"/> -205 g (original) <input type="checkbox"/> -265 g <input type="checkbox"/> -305 g <input type="checkbox"/> -360 g</p> | <p style="text-align: right;">Color: _____</p> <p>Changing Ball Circumference You will only have access to the following materials.</p> <p>General Materials: (check all that apply)</p> <p><input type="checkbox"/> (3) Timers <input type="checkbox"/> Ball stop board <input type="checkbox"/> Ruler <input type="checkbox"/> Scale <input type="checkbox"/> 300 cm measuring tape <input type="checkbox"/> 152 cm measuring tape</p> <p>Run Material: (check 1) <input type="checkbox"/> Outdoor Carpet (original)</p> <p>Run Length: (select 1) Select a run length between 50 cm and 200 cm. Run length we will use: _____</p> <p>Ramp Height: (check 1) <input type="checkbox"/> 13 cm (original) <input type="checkbox"/> 22 cm</p> <p>Ramp Length: (check 1) <input type="checkbox"/> 50 cm (original)</p> <p>Ball Circumference: (check 4 and write the trail letter after each value selected)</p> <p><input type="checkbox"/> 18 cm <input type="checkbox"/> 21 cm <input type="checkbox"/> 24 cm <input type="checkbox"/> 27 cm (original) <input type="checkbox"/> 30 cm <input type="checkbox"/> 33 cm</p> <p>Ball Mass: (check 1) <input type="checkbox"/> -205 g</p> |
| <p style="text-align: right;">Color: _____</p> <p>Changing Ramp Height You will only have access to the following materials.</p> <p>General Materials: (check all that apply)</p> <p><input type="checkbox"/> (3) Timers <input type="checkbox"/> Ball stop board <input type="checkbox"/> Ruler <input type="checkbox"/> Scale <input type="checkbox"/> 300 cm measuring tape <input type="checkbox"/> 152 cm measuring tape</p> <p>Run Material: (check 1) <input type="checkbox"/> Outdoor Carpet (original)</p> <p>Run Length: (select 1) Select a run length between 50 cm and 100 cm. Run length we will use: _____</p> <p>Ramp Height: (select 4) Select ramp heights between 10 cm and 45 cm. <input type="checkbox"/> Lab Jack <input type="checkbox"/> Ramp Height A: _____ <input type="checkbox"/> Ramp Height B: _____ <input type="checkbox"/> Ramp Height C: _____ <input type="checkbox"/> Ramp Height D: _____</p> <p>Ramp Length: (check 1) <input type="checkbox"/> 50 cm (original)</p> <p>Ball Circumference: (check 1) <input type="checkbox"/> 27 cm (original)</p> <p>Ball Mass: (check 1) <input type="checkbox"/> -205 g</p> | <p style="text-align: right;">Color: _____</p> <p>Changing Ramp Length You will only have access to the following materials.</p> <p>General Materials: (check all that apply)</p> <p><input type="checkbox"/> (3) Timers <input type="checkbox"/> Ball stop board <input type="checkbox"/> Ruler <input type="checkbox"/> Scale <input type="checkbox"/> 300 cm measuring tape <input type="checkbox"/> 152 cm measuring tape</p> <p>Run Material: (check 1) <input type="checkbox"/> Outdoor Carpet (original)</p> <p>Run Length: (select 1) Select a run length between 80 cm and 200 cm. Run length we will use: _____</p> <p>Ramp Height: (check 1) <input type="checkbox"/> 13 cm (original) <input type="checkbox"/> 22 cm</p> <p>Ramp Length: (check 4 and write the trail letter after each value selected)</p> <p><input type="checkbox"/> 45 cm (13 cm ramp only) <input type="checkbox"/> 50 cm (original) <input type="checkbox"/> 55 cm <input type="checkbox"/> 60 cm <input type="checkbox"/> 65 cm <input type="checkbox"/> 70 cm <input type="checkbox"/> 75 cm <input type="checkbox"/> 80 cm</p> <p>Ball Circumference: (check 1) <input type="checkbox"/> 27 cm (original)</p> <p>Ball Mass: (check 1) <input type="checkbox"/> -205 g</p> |
| <p style="text-align: right;">Color: _____</p> <p>Changing Run Length You will only have access to the following materials.</p> <p>General Materials: (check all that apply)</p> <p><input type="checkbox"/> (3) Timers <input type="checkbox"/> Ball stop board <input type="checkbox"/> Ruler <input type="checkbox"/> Scale <input type="checkbox"/> 300 cm measuring tape <input type="checkbox"/> 152 cm measuring tape</p> <p>Run Material: (check 1) <input type="checkbox"/> Outdoor Carpet (original)</p> <p>Run Length: (select 4) Select a run length between 50 cm and 200 cm. <input type="checkbox"/> Run Length A: _____ <input type="checkbox"/> Run Length B: _____ <input type="checkbox"/> Run Length C: _____ <input type="checkbox"/> Run Length D: _____</p> <p>Ramp Height: (select 4) Select ramp heights between 10 cm and 45 cm. <input type="checkbox"/> 13 cm (original) <input type="checkbox"/> 22 cm</p> <p>Ramp Length: (check 1) <input type="checkbox"/> 50 cm (original)</p> <p>Ball Circumference: (check 1) <input type="checkbox"/> 27 cm (original)</p> <p>Ball Mass: (check 1) <input type="checkbox"/> -205 g</p> | <p style="text-align: right;">Color: _____</p> <p>Changing Ball Mass You will only have access to the following materials.</p> <p>General Materials: (check all that apply)</p> <p><input type="checkbox"/> (3) Timers <input type="checkbox"/> Ball stop board <input type="checkbox"/> Ruler <input type="checkbox"/> Scale <input type="checkbox"/> 300 cm measuring tape <input type="checkbox"/> 152 cm measuring tape</p> <p>Run Material: (check 1) <input type="checkbox"/> Outdoor Carpet (original)</p> <p>Run Length: (select 1) Select a run length between 50 cm and 200 cm. Run length we will use: _____</p> <p>Ramp Height: (check 1) <input type="checkbox"/> 13 cm (original) <input type="checkbox"/> 22 cm</p> <p>Ramp Length: (check 1) <input type="checkbox"/> 50 cm (original)</p> <p>Ball Circumference: (check 1) <input type="checkbox"/> 27 cm (original)</p> <p>Ball Mass: (check 4 and write the trail letter after each value selected)</p> <p><input type="checkbox"/> -55 g <input type="checkbox"/> -100 g <input type="checkbox"/> -165 g <input type="checkbox"/> -205 g (original) <input type="checkbox"/> -265 g <input type="checkbox"/> -305 g <input type="checkbox"/> -360 g</p> |

Experimental Set-Up:

(5 minutes – Groups – SciTrek Volunteers)

Turn to page 7 of the notepad, while students turn to page 5 in their notebooks. Ask your group, “What did we decide was going to be the changing variable and what values of the changing variable did we choose for each trial?” Record these on the notepad. After, have students copy the changing variable and its values into their notebooks.

Ask your group, “What controls and values did we select?” Write the control on the left side of the slash and the value of the control on the right side of the slash (Ex: run material / outdoor carpet). In addition, have students copy these into their notebooks. An example filled in experimental set-up is shown below.

Once the experimental set-up is complete, have students predict what will happen in the experiment and fill in the sentence frames on page 5. The prediction sentences can be different in each student’s notebook.

If you have additional time, have your group summarize the experiment that they are going to run and what they are hoping to learn from the experiment.

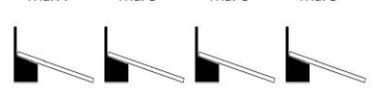
EXPERIMENTAL SET-UP

Trial A

Trial B

Trial C

Trial D



Changing Variable:
Ball Mass : ~265 g ~165 g ~55 g ~360 g

Controls (variables you will hold constant):

| | |
|-----------------------------------|--------------------------------------|
| <u>Object Type / Ball</u> | <u>Ramp Length / 50 cm</u> |
| <u>Ball Circumference / 27 cm</u> | <u>Run Material / Outdoor Carpet</u> |
| <u>Ramp Height / 22 cm</u> | <u>Run Length / 200 cm</u> |

Predictions:

I predict when the ball mass is _____
changing variable value of changing variable
 the ball will hit the board in the least amount of time.

I predict when the ball mass is _____
changing variable value of changing variable
 the ball will hit the board in the least amount of time.

7

EXPERIMENTAL SET-UP

Write your changing variable (Ex: ball mass) and the values (Ex: 15 g) you will use for your trials under each set-up.

Trial A

Trial B

Trial C

Trial D



Changing Variable:
Ball Mass : ~265 g ~165 g ~55 g ~360 g

Controls (variables you will hold constant):
 Write your controls and the values you will use in all your trials (control/value, Ex: object type/ball).

| | |
|-----------------------------------|--------------------------------------|
| <u>Object Type / Ball</u> | <u>Ramp Length / 50 cm</u> |
| <u>Ball Circumference / 27 cm</u> | <u>Run Material / Outdoor Carpet</u> |
| <u>Ramp Height / 22 cm</u> | <u>Run Length / 200 cm</u> |

Predictions

I predict that when the ball mass is _____
changing variable value of changing variable
 the ball will hit the board in the least amount of time.

I predict that when the ball mass is _____
changing variable value of changing variable
 the ball will hit the board in the most amount of time.

5

Wrap-Up:

(3 minutes – Full Class - SciTrek Lead)

Have one student from each group share the question that they will investigate. Tell students, “Next session, you will do your experiments. All of your experiments will help us answer the class question: What variables affect ball motion?”

Clean-Up:

1. Collect notebooks with attach nametag.
2. Place all materials in your group box, and bring them back to UCSB.

Day 3: Technique/Procedure/Results Table/Experiment
Schedule:

Introduction (SciTrek Lead) – 3 minutes
 Technique (SciTrek Lead) – 7 minutes
 Procedure (SciTrek Volunteers) – 18 minutes
 Results Table (SciTrek Volunteers) – 5 minutes
 Experiment (SciTrek Volunteers) – 25 minutes
 Wrap-Up (SciTrek Lead) – 2 minutes

Materials:

(4) Volunteer Boxes:

- | | | |
|---|--|---|
| <input type="checkbox"/> Student nametags | <input type="checkbox"/> (2) Grease pencil | <input type="checkbox"/> (3) Timers |
| <input type="checkbox"/> Notebooks | <input type="checkbox"/> Notepad | <input type="checkbox"/> Requested wood ramp holder or lab jack |
| <input type="checkbox"/> Volunteer instructions | <input type="checkbox"/> Measuring tape (152 cm) | <input type="checkbox"/> Requested ball(s) |
| <input type="checkbox"/> Volunteer lab coat | <input type="checkbox"/> Measuring tape (300 cm) | <input type="checkbox"/> Large binder clip |
| <input type="checkbox"/> (2) Pencils | <input type="checkbox"/> Ruler | |

Other Supplies:

- | | | |
|--|---|---|
| <input type="checkbox"/> (4) Notepads | <input type="checkbox"/> (4) Ball stop boards 65 cm x 30 cm | <input type="checkbox"/> Box with 4 electronic scales |
| <input type="checkbox"/> Requested ramps lengths | | <input type="checkbox"/> (4) 6 ft x 2 ft outdoor carpet |

Lead Box:

- | | | |
|--|--|--|
| <input type="checkbox"/> (3) Extra notebooks | <input type="checkbox"/> (2) Wet erase markers | <input type="checkbox"/> Wood ramp holder (13 cm tall) |
| <input type="checkbox"/> Lead instructions | <input type="checkbox"/> Notepad | <input type="checkbox"/> Wood ramp holder (22 cm tall) |
| <input type="checkbox"/> Motion picture packet | <input type="checkbox"/> Measuring tape (152 cm) | <input type="checkbox"/> Yellow ball (27 cm circ., ~165 g) |
| <input type="checkbox"/> Lead lab coat | <input type="checkbox"/> Measuring tape (300 cm) | <input type="checkbox"/> Green ball (27 cm circ., ~200 g) |
| <input type="checkbox"/> Time card | <input type="checkbox"/> Ruler | <input type="checkbox"/> Large binder clip |
| <input type="checkbox"/> (2) Pencils | <input type="checkbox"/> (4) Timers | |

Notebook Pages, and Notepad Pages:

TECHNIQUE
Median

When running multiple trials in an experiment it is necessary to find one number to represent all of the data. The middle number, also known as the median number, is sometimes used to represent all the data. To find the median, first place all of the numbers from each trial in increasing order, second circle the middle number.

| Ball Material: | Time Ball Travels (s): (In Increasing Order) | Median (s): |
|----------------|---|------------------|
| Styrofoam Ball | $5\frac{6}{10}$, 7, $6\frac{7}{10}$ $5\frac{6}{10}$ $6\frac{7}{10}$ 7 | $6\frac{7}{10}$ |
| Metal Ball | $2\frac{3}{10}$, $1\frac{8}{10}$, $2\frac{7}{10}$, $1\frac{4}{10}$, $1\frac{9}{10}$ $2\frac{3}{10}$ $1\frac{8}{10}$ $1\frac{4}{10}$ $2\frac{7}{10}$ $1\frac{9}{10}$ | $1\frac{4}{10}$ |
| Wooden Ball | $2\frac{7}{10}$, $2\frac{6}{10}$, $2\frac{9}{10}$ $2\frac{7}{10}$ $2\frac{6}{10}$ $2\frac{9}{10}$ | $2\frac{6}{10}$ |
| Plastic Ball | $4\frac{1}{10}$, $3\frac{7}{10}$, $4\frac{2}{10}$, $4\frac{1}{10}$, 4 $4\frac{1}{10}$ $3\frac{7}{10}$ $4\frac{2}{10}$ $4\frac{1}{10}$ 4 | $4\frac{2}{10}$ |
| Velcro Ball | $21\frac{4}{10}$, $21\frac{7}{10}$, $21\frac{9}{10}$, $20\frac{5}{10}$, $22\frac{3}{10}$ $21\frac{4}{10}$ $21\frac{7}{10}$ $21\frac{9}{10}$ $20\frac{5}{10}$ $22\frac{3}{10}$ | $21\frac{9}{10}$ |

6

PROCEDURE

1. Roll out outdoor carpet.

2. Set up ramp that is 50 cm long and 22 cm high.

3. Get balls that have a circumference of 27 cm and masses of A) 265 g, B) 165 g, C) 55 g, and D) 360 g.

4. Roll balls 200 cm and time.

5. Repeat 2 more times.

6. Find median time for each trial.

8

PROCEDURE

1. Roll out outdoor carpet.

2. Set up ramp that is 50 cm long and 22 cm high.

3. Get balls that have a circumference of 27 cm and masses of A) 265 g, B) 165 g, C) 55 g, and D) 360 g.

4. Roll balls 200 cm, and time.

5. Repeat 2 more times

6. Find median time for each trial.

7

| RESULTS Table | | | | | |
|---------------------|--------------------------------|--|--|--|--|
| Variables | Trial A | Trial B | Trial C | Trial D | |
| Object Type: | Ball | | | | |
| Ball Mass: | 265 g | 165 g | 55 g | 360 g | |
| Ball Circumference: | 27 cm | | | | |
| Run Material: | Outdoor Carpet | | | | |
| Run Length: | 200 cm | | | | |
| Ramp Height: | 22 cm | | | | |
| Ramp Length: | 50 cm | | | | |
| Data | Trial A | Trial B | Trial C | Trial D | |
| Measurements: | 1 | 1 | 1 | 1 | |
| | $\frac{1}{10}$ s | $\frac{1}{10}$ s | $\frac{1}{10}$ s | $\frac{1}{10}$ s | |
| | 2 | 2 | 2 | 2 | |
| | $\frac{1}{10}$ s | $\frac{1}{10}$ s | $\frac{1}{10}$ s | $\frac{1}{10}$ s | |
| | 3 | 3 | 3 | 3 | |
| | $\frac{1}{10}$ s | $\frac{1}{10}$ s | $\frac{1}{10}$ s | $\frac{1}{10}$ s | |
| | Put Times in Increasing Order: | $\frac{1}{10}$ s, $\frac{1}{10}$ s, $\frac{1}{10}$ s |
| | Median: | $\frac{1}{10}$ s | $\frac{1}{10}$ s | $\frac{1}{10}$ s | $\frac{1}{10}$ s |

| RESULTS Table | | | | | |
|---|------------------------------------|--|--|--|--|
| Fill out the table for each of your trials. For the variables that remain constant, write the value in Trial A. Then, draw an arrow through each box to indicate the variable is a control. | | | | | |
| Variables | Trial A | Trial B | Trial C | Trial D | |
| Object Type: | Ball | | | | |
| Ball Mass: | 265 g | 165 g | 55 g | 360 g | |
| Ball Circumference: | 27 cm | | | | |
| Run Material: | Outdoor Carpet | | | | |
| Run Length: | 200 cm | | | | |
| Ramp Height: | 22 cm | | | | |
| Ramp Length: | 50 cm | | | | |
| Data | Trial A | Trial B | Trial C | Trial D | |
| Measurements: | 1 | 1 | 1 | 1 | |
| | $\frac{1}{10}$ s | $\frac{1}{10}$ s | $\frac{1}{10}$ s | $\frac{1}{10}$ s | |
| | 2 | 2 | 2 | 2 | |
| | $\frac{1}{10}$ s | $\frac{1}{10}$ s | $\frac{1}{10}$ s | $\frac{1}{10}$ s | |
| | 3 | 3 | 3 | 3 | |
| | $\frac{1}{10}$ s | $\frac{1}{10}$ s | $\frac{1}{10}$ s | $\frac{1}{10}$ s | |
| | Put Times 1-3 in Increasing Order: | $\frac{1}{10}$ s , $\frac{1}{10}$ s , $\frac{1}{10}$ s | $\frac{1}{10}$ s , $\frac{1}{10}$ s , $\frac{1}{10}$ s | $\frac{1}{10}$ s , $\frac{1}{10}$ s , $\frac{1}{10}$ s | $\frac{1}{10}$ s , $\frac{1}{10}$ s , $\frac{1}{10}$ s |
| | Median: | $\frac{1}{10}$ s | $\frac{1}{10}$ s | $\frac{1}{10}$ s | $\frac{1}{10}$ s |

The independent variable is the changing variable and the dependent variables are the measurements.

Preparation:

SciTrek Lead:

1. Make sure volunteers are passing out notebooks.
2. Make sure volunteers are setting materials that they will use with their group on the floor.
3. Set up the document camera for the technique activity (page 6, notebook).

SciTrek Volunteers:

1. Pass out notebooks/nametags.
2. Get materials your group requested and place them in a pile on the floor where they will be doing their experiment, but do not set them up. Make sure you get the correct ramp length piece(s).

Introduction:

(3 minutes – Full Class – SciTrek Lead)

Ask the class, “What is the class question we are investigating?” Students should reply, “What variables affect ball motion?” Ask students, “What have we already learned about ball motion?” Possible student response: we learned that the smoother the run material the shorter the time it takes for the ball to hit the board. Remind students last time they picked another variable they are going to explore for their experiment. Ask students, “Are you going to run one or multiple trials?” They should reply, “Multiple trials.” Ask students, “If you have multiple different numbers for each trial, what number will you use for your graph?” Students should reply, “The middle number, which is called the median.” Ask students, “Why is the median the best option to graph?” Possible student response: the median is a good representation of the data. Tell students, “We are now going to practice finding the median from other scientists’ data.”

Technique:

(7 minutes – Full Class – SciTrek Lead)

Have students turn to page 6 in their notebooks while you do the same in the class notebook under the document camera. Tell students, “To find the median, you need to arrange the numbers in increasing order. Once the numbers are arranged in order, the number in the middle is the median number, which you should identify by circling.” Go over how to find the median in the first two examples and then have the students work on the rest by themselves. After students have finished, go over the answers. An example notebook page can be found below.

Tell students, “You will use this technique of finding the median when you perform your experiment.”

Tell students, “But before you can carry out your experiment, you need to write a procedure.” Ask the class, “What is a procedure?” Lead students to understand that it is a set of steps to conduct an experiment. Tell them, “Once you have determined your procedure, you will fill out their results table and carry out your experiment.”

TECHNIQUE
Median

When running multiple trials in an experiment it is necessary to find one number to represent all of the data. The middle number, also known as the median number, is sometimes used to represent all the data. To find the median, first place all of the numbers from each trial in increasing order, second circle the middle number.

| Ball Material: | Time Ball Travels (s): (In Increasing Order) | Median (s): |
|----------------|--|------------------|
| Styrofoam Ball | $5\frac{6}{10}$, 7, $6\frac{7}{10}$ $5\frac{6}{10}$ 7 $6\frac{7}{10}$ | $6\frac{7}{10}$ |
| Metal Ball | $2\frac{3}{10}$, $1\frac{2}{10}$, $2\frac{7}{10}$, $1\frac{4}{10}$, $1\frac{5}{10}$ $2\frac{3}{10}$ $1\frac{2}{10}$ $1\frac{4}{10}$ $2\frac{7}{10}$ $1\frac{5}{10}$ | $1\frac{4}{10}$ |
| Wooden Ball | $2\frac{7}{10}$, $2\frac{6}{10}$, $2\frac{9}{10}$ $2\frac{7}{10}$ $2\frac{6}{10}$ $2\frac{9}{10}$ | $2\frac{6}{10}$ |
| Plastic Ball | $4\frac{1}{10}$, $3\frac{2}{10}$, $4\frac{2}{10}$, $4\frac{1}{10}$, 4 $4\frac{1}{10}$ $3\frac{2}{10}$ $4\frac{1}{10}$ $4\frac{2}{10}$ 4 | $4\frac{1}{10}$ |
| Velcro Ball | $21\frac{4}{10}$, $21\frac{7}{10}$, $21\frac{9}{10}$, $20\frac{6}{10}$, $22\frac{3}{10}$ $21\frac{4}{10}$ $21\frac{7}{10}$ $21\frac{9}{10}$ $21\frac{6}{10}$ $22\frac{3}{10}$ | $21\frac{6}{10}$ |

6

Procedure:

(18 minutes – Groups – SciTrek Volunteers)

Ask students, “What did you pick for the changing variable and what do you think we will learn from the experiment?”

Tell students, “You will now generate a procedure for your experiment.” Ask students, “What is a procedure?” Students should reply, “A set of steps to conduct an experiment.” Then, help students generate a procedure. Keep the procedure as brief as possible while still including the important information (control values, changing variable values, and what data they will collect) about the experiment. An example step for a group that had ball mass as the changing variable would be: “Get balls

with a 27 cm circumference and masses of A) 250 g, B) 150 g, C) 50 g, and D) 350 g.” Have students dictate the procedure to you while you transcribe it onto the notepad. As each step is completed, have students copy it from the notepad into their notebooks. Make sure that you do not continue on to the next step until each student has completed writing that step. An example filled in procedure is shown below.

PROCEDURE

1. Roll out outdoor carpet.

2. Set up ramp that is 50 cm long and 22 cm high.

3. Get balls that have a circumference of 27 cm and masses of A) 265 g, B) 165 g, C) 55 g, and D) 360 g.

4. Roll balls 200 cm and time.

5. Repeat 2 more times.

6. Find median time for each trial.

8

PROCEDURE

1. Roll out outdoor carpet.

2. Set up ramp that is 50 cm long and 22 cm high.

3. Get balls that have a circumference of 27 cm and masses of A) 265 g, B) 165 g, C) 55 g, and D) 360 g.

4. Roll balls 200 cm, and time.

5. Repeat 2 more times

6. Find median time for each trial.

7

Results Table:

(5 minutes – Groups – SciTrek Volunteers)

Fill out the variables section of the results table while students fill out the same section in their notebooks. When writing the values, make sure, for controls, they only write the value of the control in the trial A box, then, draw an arrow through the remaining trials’ boxes. For the changing variable, they should write the value in each trial’s corresponding box. An example filled out results table is shown in the Experiment Section below.

Experiment:

(25 minutes – Groups – SciTrek Volunteers)

Once students have completed the variables section of their results table, have students move to their materials on the floor. Volunteers will fill out all data on the notepad and students' notebooks will be left at the tables during the experiment. Once experiments are completed, students will return to the tables and copy the data into their own notebooks.

Help students set up and complete their experiment. For each trial, your group will roll the ball three times. For each roll, there will be three students timing the ball. This will give you nine total times for each trial. Record the data students collect on a paper notepad (found in your box). Then, have students tell you how to arrange the numbers from smallest to largest and copy them into the notepad (see below). For each ball roll, have students identify the median from your recorded numbers. This should be done before the ball is rolled again. The median number is the only number students will record in their notebooks. On the notepad, each trial will have a total of nine recorded times. The notebooks will have three numbers recorded for each trial. Remember to record time to the nearest fraction of a second (Ex: $1\frac{3}{10}$ s). Once all trials are completed and all data has been recorded, bring students back to their desks and have students copy the data into their notebooks.

Note: The actual ball masses can be off by up to 5 g off from the mass on the materials page. But just let students use the mass on the materials page.

When students are finished copying the group data into their notebooks, have students put the times for trial A in ascending order and determine the median number for that trial. Then, have students work independently to find the median number for the rest of the trials. After students are finished, go over the median numbers as a group and record the numbers on the notepad. An example filled out result table is shown below.

| RESULTS Table | | | | | |
|---------------------|----------------------------------|--|--|--|---|
| Variables | Trial A | Trial B | Trial C | Trial D | |
| Object Type: | Ball \longrightarrow | | | | |
| Ball Mass: | 265 g | 165 g | 55 g | 360 g | |
| Ball Circumference: | 27 cm \longrightarrow | | | | |
| Run Material: | Outdoor Carpet \longrightarrow | | | | |
| Run Length: | 200 cm \longrightarrow | | | | |
| Ramp Height: | 22 cm \longrightarrow | | | | |
| Ramp Length: | 50 cm \longrightarrow | | | | |
| Data | Trial A | Trial B | Trial C | Trial D | |
| Measurements: | Time: | $1\frac{6}{10}$ s $1\frac{7}{10}$ s $1\frac{8}{10}$ s $1\frac{9}{10}$ s $1\frac{10}{10}$ s $1\frac{11}{10}$ s $1\frac{12}{10}$ s $1\frac{13}{10}$ s $1\frac{14}{10}$ s | $1\frac{6}{10}$ s $1\frac{7}{10}$ s $1\frac{8}{10}$ s $1\frac{9}{10}$ s $1\frac{10}{10}$ s $1\frac{11}{10}$ s $1\frac{12}{10}$ s $1\frac{13}{10}$ s $1\frac{14}{10}$ s | $1\frac{8}{10}$ s $1\frac{9}{10}$ s $1\frac{10}{10}$ s $1\frac{11}{10}$ s $1\frac{12}{10}$ s $1\frac{13}{10}$ s $1\frac{14}{10}$ s $1\frac{15}{10}$ s $1\frac{16}{10}$ s | $1\frac{7}{10}$ s $1\frac{8}{10}$ s $1\frac{9}{10}$ s $1\frac{10}{10}$ s $1\frac{11}{10}$ s $1\frac{12}{10}$ s $1\frac{13}{10}$ s $1\frac{14}{10}$ s $1\frac{15}{10}$ s |
| | Put Times in Increasing Order: | $1\frac{6}{10}$ s, $1\frac{7}{10}$ s, $1\frac{8}{10}$ s, $1\frac{9}{10}$ s, $1\frac{10}{10}$ s, $1\frac{11}{10}$ s, $1\frac{12}{10}$ s, $1\frac{13}{10}$ s, $1\frac{14}{10}$ s | $1\frac{6}{10}$ s, $1\frac{7}{10}$ s, $1\frac{8}{10}$ s, $1\frac{9}{10}$ s, $1\frac{10}{10}$ s, $1\frac{11}{10}$ s, $1\frac{12}{10}$ s, $1\frac{13}{10}$ s, $1\frac{14}{10}$ s | $1\frac{8}{10}$ s, $1\frac{9}{10}$ s, $1\frac{10}{10}$ s, $1\frac{11}{10}$ s, $1\frac{12}{10}$ s, $1\frac{13}{10}$ s, $1\frac{14}{10}$ s, $1\frac{15}{10}$ s, $1\frac{16}{10}$ s | $1\frac{7}{10}$ s, $1\frac{8}{10}$ s, $1\frac{9}{10}$ s, $1\frac{10}{10}$ s, $1\frac{11}{10}$ s, $1\frac{12}{10}$ s, $1\frac{13}{10}$ s, $1\frac{14}{10}$ s, $1\frac{15}{10}$ s |
| | Median: | $1\frac{7}{10}$ s | $1\frac{8}{10}$ s | $1\frac{10}{10}$ s | $1\frac{10}{10}$ s |

| RESULTS Table | | | | | |
|---|---|---|--|--|---|
| Fill out the table for each of your trials. For the variables that remain constant, write the value in Trial A. Then, draw an arrow through each box to indicate the variable is a control. | | | | | |
| Variables | Trial A | Trial B | Trial C | Trial D | |
| Object Type: | Ball \longrightarrow | | | | |
| Ball Mass: | 265 g | 165 g | 55g | 360 g | |
| Ball Circumference: | 27 cm \longrightarrow | | | | |
| Run Material: | Outdoor Carpet \longrightarrow | | | | |
| Run Length: | 200 cm \longrightarrow | | | | |
| Ramp Height: | 22 cm \longrightarrow | | | | |
| Ramp Length: | 50 cm \longrightarrow | | | | |
| Data | Trial A | Trial B | Trial C | Trial D | |
| Measurements: | Time: | $1\frac{7}{10}$ s $1\frac{8}{10}$ s $1\frac{9}{10}$ s $1\frac{10}{10}$ s $1\frac{11}{10}$ s $1\frac{12}{10}$ s $1\frac{13}{10}$ s $1\frac{14}{10}$ s | $1\frac{6}{10}$ s $1\frac{7}{10}$ s $1\frac{8}{10}$ s $1\frac{9}{10}$ s $1\frac{10}{10}$ s $1\frac{11}{10}$ s $1\frac{12}{10}$ s $1\frac{13}{10}$ s | $1\frac{8}{10}$ s $1\frac{9}{10}$ s $1\frac{10}{10}$ s $1\frac{11}{10}$ s $1\frac{12}{10}$ s $1\frac{13}{10}$ s $1\frac{14}{10}$ s $1\frac{15}{10}$ s | $1\frac{7}{10}$ s $1\frac{8}{10}$ s $1\frac{9}{10}$ s $1\frac{10}{10}$ s $1\frac{11}{10}$ s $1\frac{12}{10}$ s $1\frac{13}{10}$ s $1\frac{14}{10}$ s |
| | Put Times 1-3 in Increasing Order: | $1\frac{7}{10}$ s , $1\frac{8}{10}$ s , $1\frac{9}{10}$ s | $1\frac{6}{10}$ s , $1\frac{7}{10}$ s , $1\frac{8}{10}$ s | $1\frac{8}{10}$ s , $1\frac{9}{10}$ s , $1\frac{10}{10}$ s | $1\frac{7}{10}$ s , $1\frac{8}{10}$ s , $1\frac{9}{10}$ s |
| | Median: | $1\frac{7}{10}$ s | $1\frac{7}{10}$ s | $1\frac{9}{10}$ s | $1\frac{8}{10}$ s |
| | The independent variable is the changing variable and the dependent variables are the measurements. | | | | |

If there is additional time, have students explain to you how they set up for their experiment and what they learned from their experiment. Try to have students explain this without looking at their notebooks.

Wrap-Up:

(2 minutes – Full Class – SciTrek Lead)

Tell students, “Next session, you will analyze your data by making a graph as well as a poster, which you will use to present your findings to the class. These posters will help us learn about what variables affect ball motion.

Clean-Up:

1. Collect notebooks with attached nametags.
2. Place ramps and runs in the appropriate bags.
3. Place all other materials in your group box, and bring them back to UCSB.

Day 4: Graph/Results Summary/Poster Making

Schedule:

Introduction (SciTrek Lead) – 2 minutes
 Graph (SciTrek Volunteers) – 10 minutes
 Results Summary (SciTrek Volunteers) – 10 minutes
 Poster Making (SciTrek Volunteers) – 33 minutes
 Wrap-Up (SciTrek Lead) – 5 minutes

Materials:

(4) Volunteer Boxes:

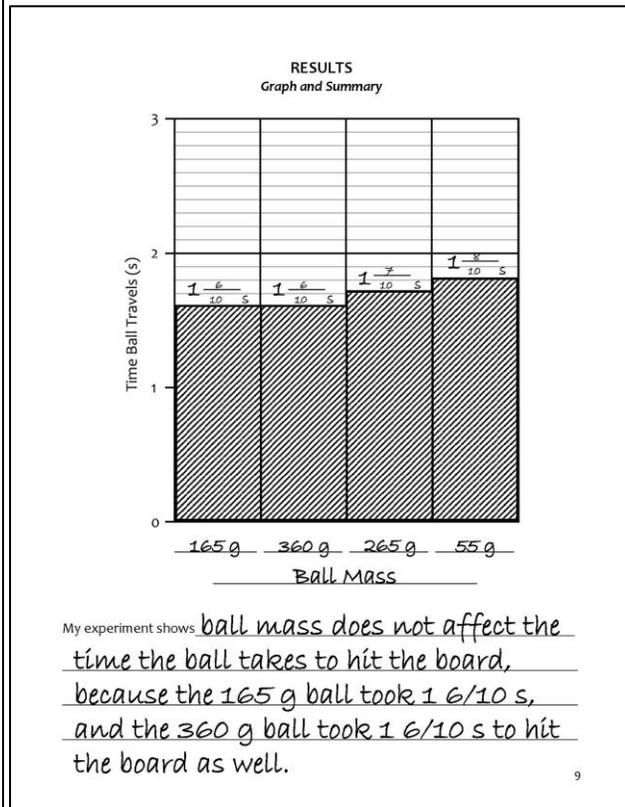
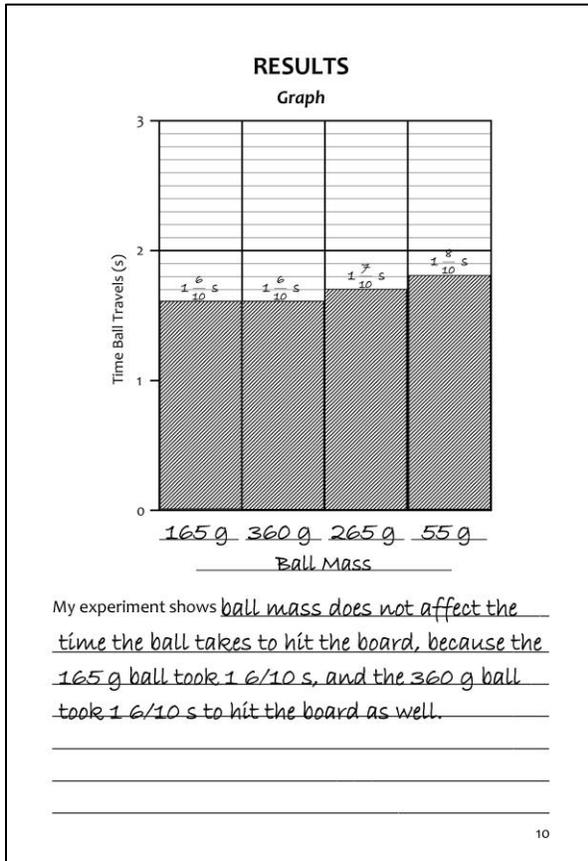
- | | | |
|---|---|--|
| <input type="checkbox"/> Nametags | <input type="checkbox"/> (8) Partial graph pieces | <input type="checkbox"/> Scotch tape |
| <input type="checkbox"/> Notebooks | <input type="checkbox"/> (2) Pencils | <input type="checkbox"/> Poster parts pack (scientists’ names, question, experimental set-up, procedure, results table, results graph, results summary, (6) <i>I acted like a scientist when</i> , (6) picture spaces) |
| <input type="checkbox"/> Volunteer instructions | <input type="checkbox"/> (5) Paperclips | |
| <input type="checkbox"/> Volunteer lab coat | <input type="checkbox"/> (2) Grease pencil | |
| <input type="checkbox"/> Poster diagram | <input type="checkbox"/> Highlighter | |
| <input type="checkbox"/> Appropriate sticker for how to present graph (changing ball or ramp) | <input type="checkbox"/> Scissors | |
| | <input type="checkbox"/> (2) Glues | |

Other Supplies:

- | | |
|---------------------------------------|--|
| <input type="checkbox"/> (4) Notepads | <input type="checkbox"/> Poster paper tube |
|---------------------------------------|--|

Lead Box:

- | | | |
|--|---|---|
| <input type="checkbox"/> (3) Extra notebooks | <input type="checkbox"/> (2) Sticker sets for how to present graph (changing ball and ramp) | <input type="checkbox"/> (2) Highlighters |
| <input type="checkbox"/> Lead instructions | <input type="checkbox"/> (8) Partial graph pieces | <input type="checkbox"/> Scissors |
| <input type="checkbox"/> Motion picture packet | <input type="checkbox"/> (2) Pencils | <input type="checkbox"/> (2) Glues |
| <input type="checkbox"/> Poster diagram | <input type="checkbox"/> (5) Paperclips | <input type="checkbox"/> Scotch tape |
| <input type="checkbox"/> Lead lab coat | <input type="checkbox"/> (2) Wet erase markers | <input type="checkbox"/> (1 each color) Poster part packs |
| <input type="checkbox"/> Time card | | |

Notebook Page, and Notepad Page:

Preparation:

SciTrek Lead:

1. Make sure volunteers are setting out notebooks.
2. Ask the classroom teacher for a place to leave student posters.

SciTrek Volunteers:

1. Set out notebooks/nametags.

Note: Set notebooks where students will sit during the module even if another student is currently at that desk. If needed, students will move to these spots after the Introduction.

Introduction:

(2 minutes – Full Class – SciTrek Lead)

If students are not in their groups, tell them, “A notebook will be put on your desk, which is not your notebook and you should not move it. You will move to your groups after the Introduction.”

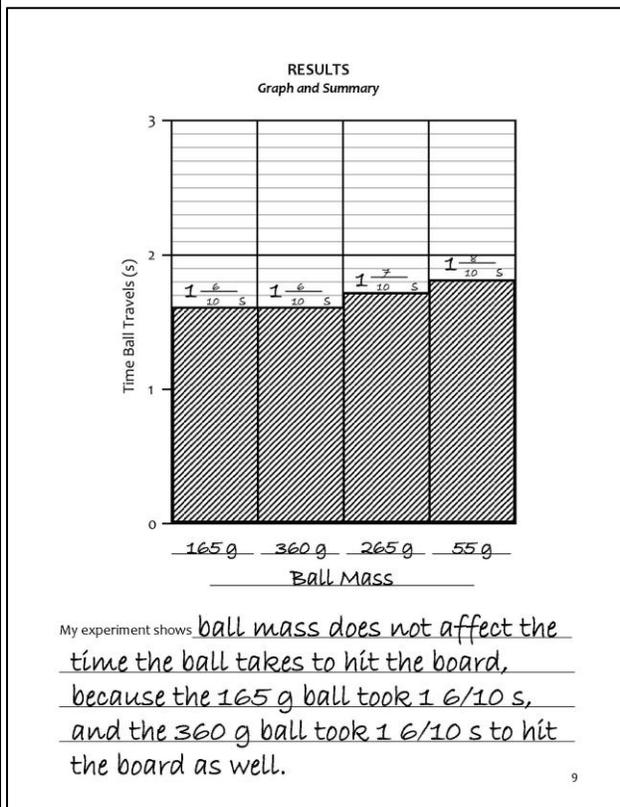
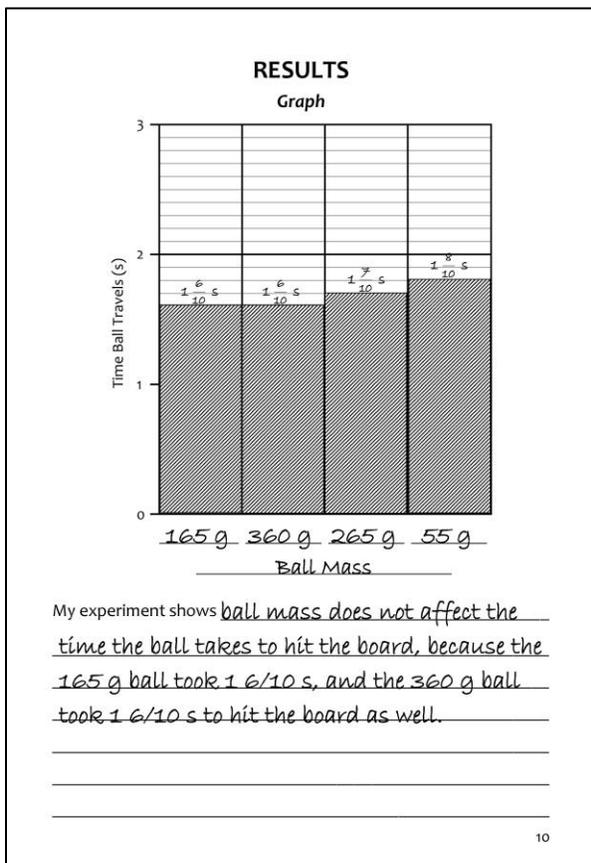
Ask the class, “What is the class question that we have been investigating?” Students should reply, “What variables affect ball motion?” Tell students, “Today you are going to analyze the results from your experiments, which will allow you to start answering the class question. You will then put together a poster to present your findings to the class. You should write as neatly as possible on the poster parts so that the other class members can read your poster.”

Graph:

(10 minutes – Groups – SciTrek Volunteers)

Ask your group, “What did we do last time in SciTrek?” Have them explain their experiment to you without looking at their notebooks.

Pass out one partial graph piece to each student and have them fill out the piece for the trial they oversaw. There is an extra partial graph piece in the group box that you should use as an example. On the bottom line, have students write the value of their changing variable (Ex: 150 g), not the trial letter or the changing variable (Ex: A or ball mass). This way, when the pieces are rearranged, they will be able to see the changing variable values for each of the trials to help them identify any patterns. The graph will have a scale provided. Each large line represents 1 second, each smaller line represents $\frac{1}{10}$ of a second. Have students draw a line across the column showing the median time for their trial, as well as, write in the numerical value of the time on top of the line, and then quickly shade below the line. Once each student has completed their graph piece, have students help you arrange the partial graph pieces so they are in increasing order as done in the example below. In the example experiment discussed, the trials were graphed in the following order: B, A, C, D. Tape the partial graphs to the notepad so they look like a complete graph (see below). When taping the graph pieces to the notepad, make sure that each graph piece overlaps with the one next to it, so that you only see the y-axis for the first graph piece.



After the pieces of the graph are taped into the group notepad, ask students, “What is our changing variable?” Record this answer as the x-axis title, and have students copy this into their notebooks.

Results Summary:

(10 minutes – Groups – SciTrek Volunteers)

Have your group use their graph to look for a pattern in their data. Challenge your group to think about how their changing variable did, or did not, affect ball motion.

When writing their results summary (page 9, notebook), make sure your group begins the statement with a claim (a statement that can be tested) about the trend, or pattern, in their data. If the values of their changing variable have an order (Ex: 13 cm → 15 cm → 25 cm), then that variable does have an effect on ball motion. If, on the other hand, there was no order for their changing variable values (Ex: 150 g → 250 g → 50 g) and/or the difference between the times for each trial is small, then that variable does not have an effect of ball motion. If possible, try to have your group generate a claim that allows them to make predictions about something they have not tested. An appropriate claim could be: ball mass does not affect the time the ball travels. This is an appropriate claim because it allows groups to make a prediction about what would happen if new values of their changing variable were introduced.

After generating a claim about their experiment, write the word “because,” and follow it with supporting data. Their supporting data should include at least two pieces of data, typically the minimum, and maximum, times. Make sure your group is using their changing variable values (not trial letters), and specific measurements, to support their claim. The supporting data for the previously mentioned claim would be: because the 165 g ball took $1\frac{6}{10}$ s, and the 360 g ball took $1\frac{6}{10}$ s to hit the board as well.

Results summaries are still valid, and important, if they show the changing variable tested does not affect ball motion. Even if their results summary is contrary to what you think, have your group make a claim based solely on their data. Help students copy this statement into their notebooks.

Once students have filled out the results summary, have them fill in the sentence frame (page 10, notebook): *I acted like a scientist when*. Each student’s response should be unique and specific. They should NOT write, “when I did an experiment,” because this is general, and applies to all of the students in the class. If students are having trouble with this sentence frame, ask them, “What did you do during SciTrek?”

Poster Making:

(33 minutes – Groups – SciTrek Volunteers)

Pass out the writing portions (general poster parts and *I acted like a scientist when*) and have students write their names on them and complete them. In addition, have each student write their name on the scientists’ names poster part. Use the following guidelines when assigning poster parts:

| Number of Students in Group | Poster Division |
|-----------------------------|---|
| 4 | Each student gets an <i>I acted like a scientist when</i> and picture space. 1. Question and Experimental Set-Up 2. Procedure 3. Results Graph* 4. Results Summary Student that finishes 1 st completes the results table (<u>not</u> presented) |
| 5 | 1. Question 2. Experimental Set-Up 3. Procedure 4. Results Graph* 5. Results Summary Student that finishes 1 st completes the results table (<u>not</u> presented) |
| 6 | 1. Question 2. Experimental Set-Up 3. Procedure (Presents 1 st half of procedure) 4. Results Table (Presents 2 nd half of procedure) 5. Results Graph* 6. Results Summary |

*Give the results graph to the student who is most confident in presenting.

Once students have finished their written section(s), have them draw a picture of their experiment or how they acted like a scientist.

In the students' notebooks, highlight and number the section(s) that they will present. The parts should be numbered as follows: 1) scientists' names, 2) question, 3) experimental set-up, 4) procedure, 5) results graph, and 6) results summary (see example below). Students will NOT present the results table or *I acted like a scientist when* parts from their poster. If a student is presenting multiple sections, use the paperclips in your group box to clip together the sections they are reading so that when presenting, it will be easy for them to flip back and forth between the pages.

Experimental Considerations:

- You will only have access to the materials on the materials page.
- You will run four trials.
- For each trial you must measure the time the ball travels (time from ball release to ball hitting the board) three times.

Changing Variable (Independent Variable): Ball Mass

Discuss with your group how you think your changing variable will affect ball motion.

#1 The scientists in our group are

#2 QUESTION

Question our group will investigate:

- If we change the ball mass what will happen to the time the ball takes to hit the board?

Insert what you are measuring (dependent variable)

Fill out the materials page with your SciTrek volunteer before moving onto the experimental set-up.

#3 EXPERIMENTAL SET-UP

Write your changing variable (Ex: ball mass) and the values (Ex: 15 g) you will use for your trials under each set-up.

| | | | |
|---------|---------|---------|---------|
| Trial A | Trial B | Trial C | Trial D |
|---------|---------|---------|---------|

Changing Variable:
Ball Mass : 265 g 165 g 55 g 360 g

Controls (variables you will hold constant):
Write your controls and the values you will use in all your trials (control/value, Ex: object type/ball).

| | |
|----------------------------|-------------------------------|
| Object Type / Ball | Ramp Length / 50 cm |
| Ball Circumference / 27 cm | Run Material / Outdoor Carpet |
| Ramp Height / 22 cm | Run Length / 200 cm |

Predictions

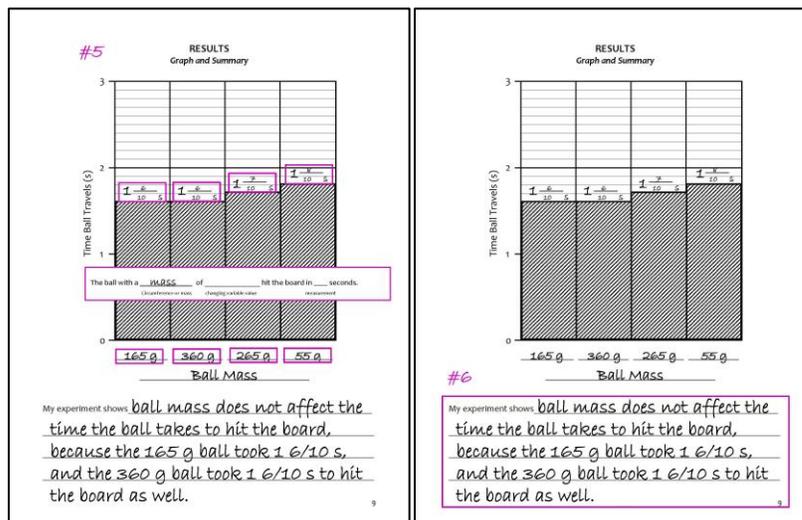
I predict that when the ball mass is 360 g the ball will hit the board in the least amount of time.

I predict that when the ball mass is 55 g the ball will hit the board in the most amount of time.

#4 PROCEDURE

- Roll out outdoor carpet.
- Set up ramp that is 50 cm long and 22 cm high.
- Get balls that have a circumference of 27 cm and masses of A) 265 g, B) 165 g, C) 55 g, and D) 360 g.
- Roll balls 200 cm, and time.
- Repeat 2 more times
- Find median time for each trial.

Ex: Highlighted/Numbered Notebook



Place one of the following sentence frame stickers on the notebook page of the student who is presenting the results graph (page 9, notebook).

Changing Ball Circumference/Mass:

The ball with a _____ (you should fill this blank out for the student) of _____ hit the board in _____ seconds.
 circumference or mass changing variable value measurement

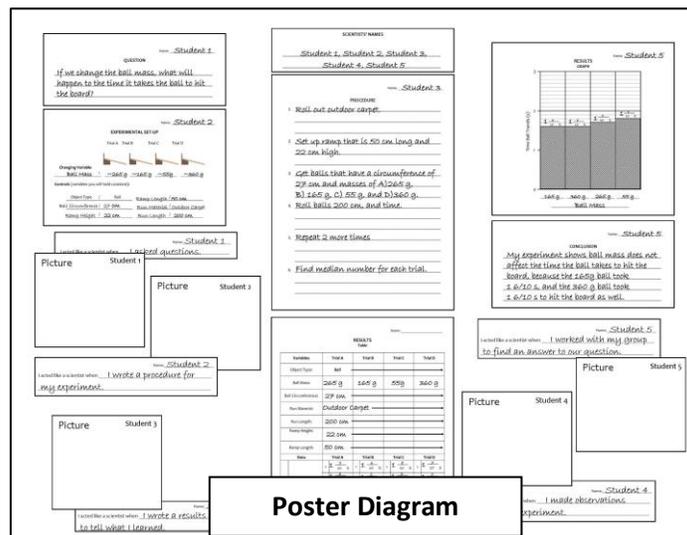
Changing Ramp Length/Height and Run Length:

The ball on the _____ (you should fill this blank out for the student) ramp hit the board in _____ seconds.
 changing variable value tall or long measurement

Then, practice reading the four sentences with that student. For the graph above, the first sentence would read: The ball with mass of **165 g** hit the board in $1\frac{6}{10}$ seconds. Make sure you fill in the first blank in the first sentence frame (Ex: mass) for the student, but leave the *changing variable value* and *measurement* blanks empty. An example of a sentence for a group that changed ramp height would read: The ball on the **30 cm tall** ramp hit the board in $1\frac{3}{10}$ seconds. Make sure you fill in the second blank in the second sentence frame (Ex: tall) for the student, but leave the *changing variable value* and *measurement* blanks empty. If your group's changing variable was run length, use the second sentence frame, but cross out the word *ramp* and change it to the word "run." An example of a sentence for a group that changed run length would read: The ball on the **100 cm long ramp** run hit the board in $1\frac{0}{10}$ seconds.

As soon as students have completed some of their pieces, start gluing them onto the large poster paper, in landscape orientation, exactly as they are arranged in the example below. Do not allow students to glue the poster parts on the poster. Do not wait until students have completed all the pieces to start gluing them onto the poster.

Once the poster is complete, have students start practicing for the presentation. Make sure students read from their notebooks, instead of from the poster.



Ask your group a few questions about their poster. Have them use their findings to predict what would happen to ball motion for other changing variable values they did not test. For instance, if the group's results summary was, "My experiment shows that ball mass does not affect the time the ball takes to hit the board, because the 165 g ball took $1\frac{6}{10}$ s, and the 360 g ball took $1\frac{6}{10}$ s to hit the board as well," ask the group, "If you tested a 500 g ball, how much time would it take to hit the board?" They should be able to predict that it would be $1\frac{6}{10}$ s.

If there is additional time, tell students, "Other students will ask you questions during your poster presentations. We should think about what questions you might be asked, and then think of the answers to those questions, so you will be prepared during your presentation."

Wrap-Up:

(5 minutes – Full Class – SciTrek Lead)

Ask students the following questions:

- How did you act like a scientist during this project?
- What did you do, that scientists do?

After discussing how they acted like scientists and talking about how everyone does things scientists do in their everyday lives, tell students, "Next session, you will present your findings to the class, and I am looking forward to hearing about all of your experiments."

Clean-Up:

1. Collect notebooks with attached nametags.
2. Leave posters in the classroom.
3. Place all other materials in your group box, and bring them back to UCSB.

Day 5: Poster Presentations

Schedule:

Introduction (SciTrek Lead) – 2 minutes
 Practice Posters (SciTrek Volunteers) – 15 minutes
 Poster Presentations (SciTrek Volunteers/SciTrek Lead) – 41 minutes
 Wrap-Up (SciTrek Lead) – 2 minutes

Materials:

(4) Volunteer Boxes:

- | | | |
|---|---|---|
| <input type="checkbox"/> Nametags | <input type="checkbox"/> Volunteer lab coat | <input type="checkbox"/> (2) Paperclips |
| <input type="checkbox"/> Notebooks | <input type="checkbox"/> (2) Pencils | <input type="checkbox"/> Highlighter |
| <input type="checkbox"/> Volunteer instructions | | |

Lead Box:

- | | | |
|--|---|--|
| <input type="checkbox"/> (3) Extra notebooks | <input type="checkbox"/> (2) Sticker sets for how to present graph (changing ball and ramp) | <input type="checkbox"/> (2) Wet erase markers |
| <input type="checkbox"/> Lead instructions | <input type="checkbox"/> (2) Pencils | <input type="checkbox"/> (4) Paperclips |
| <input type="checkbox"/> Motion picture packet | | <input type="checkbox"/> (2) Highlighters |
| <input type="checkbox"/> Lead lab coat | | <input type="checkbox"/> Scotch tape |
| <input type="checkbox"/> Time card | | |

*Student posters should already be in the classroom.

Picture Packet Page:

| What variables affect ball motion? | | | | |
|---|------------------|------------------|------------------|------------------|
| Group 1 | | | | |
| Changing Variable: | 30 | 20 | 45 | 10 |
| Ramp height (cm) | | | | |
| Time for ball to hit board (s): | $1 \frac{7}{10}$ | $1 \frac{7}{10}$ | $1 \frac{7}{10}$ | $1 \frac{7}{10}$ |
| Summary: <u>If a ramp is tall or short, the ball takes longer to hit the board. The ball takes less time if the ramp is mid-height.</u> | | | | |
| Group 2 | | | | |
| Changing Variable: | 24 | 30 | 18 | 33 |
| Ball circumference (cm) | | | | |
| Time for ball to hit board (s): | $1 \frac{6}{10}$ | $1 \frac{6}{10}$ | $1 \frac{6}{10}$ | $1 \frac{7}{10}$ |
| Summary: <u>Ball circumference does not affect the time it takes the ball to hit the board.</u> | | | | |
| Group 3 | | | | |
| Changing Variable: | ~360 | ~100 | ~165 | ~305 |
| Ball Mass (g) | | | | |
| Time for ball to hit board (s): | $1 \frac{3}{10}$ | $1 \frac{3}{10}$ | $1 \frac{3}{10}$ | $1 \frac{4}{10}$ |
| Summary: <u>Ball mass does not affect the time it takes the ball to hit the board.</u> | | | | |
| Group 4 | | | | |
| Changing Variable: | ~165 | ~360 | ~265 | ~55 |
| Ball Mass (g) | | | | |
| Time for ball to hit board (s): | $1 \frac{6}{10}$ | $1 \frac{6}{10}$ | $1 \frac{7}{10}$ | $1 \frac{8}{10}$ |
| Summary: <u>Agrees with previous group.</u> | | | | |
| Page 2, Picture Packet | | | | 2 |

Preparation:

SciTrek Lead:

1. Make sure volunteers are setting out notebooks.
2. Assign volunteers a new group to work with. This will allow students to explain what they found and practice their poster with a new person.
3. Set up the document camera for the *Notes on Presentations* (page 2, picture packet).
4. Organize posters so experiments featuring the same changing variable are presented back to back and posters are presented from simplest to most difficult to understand (suggested order: run length, ramp height, ramp length, ball circumference, ball mass).

SciTrek Volunteers:

1. Today you will initially work with a new group of students. When your original group presents their poster, go up with them.
2. Set out notebooks/nametags.

Note: Set notebooks where students will sit during the module even if another student is currently at that desk. If needed, students will move to these spots after the Introduction.

Introduction:

(2 minutes – Full Class – SciTrek Lead)

If students are not in their group, tell them, “A notebook will be put on your desk, which is not your notebook and you should not move it. You will move to your group after the Introduction.”

Tell students, “Today you will present your posters to the class. This is a common practice in science. Scientists go to conferences where they present posters about the experiments they conducted. At these presentations, other scientists give them feedback on their experiments, which allows them to return to the lab with new ideas for future experiments. Today you will work with a new volunteer. You will have 15 minutes to discuss your experiment, and results, as well as practice presenting their poster with your group. When you present you should read from your notebooks, not the posters. After practicing, you will return to your normal classroom seats.”

Practice Posters:

(15 minutes – Groups – SciTrek Volunteers)

Have volunteers rotate groups.

If the posters are not already in order, the lead should organize posters so experiments featuring the same changing variable are presented back to back and posters are presented from simplest to most difficult to understand (suggested order: run length, ramp height, ramp length, ball circumference, ball mass).

Have students explain what they did and what they learned from their experiment, without looking at their notebooks, if possible. Ask students questions to make sure they understand what they did during their experiment. Make sure you also have them use their results to predict what would happen for other systems they did not actually test. Remind them to think about patterns or trends they saw for their own results, and apply these trends to make predictions about ball motion. For instance, if the group’s changing variable was ball mass, ask them, “How much time do you think it would take for a ball of mass 125 g (this would be a mass that they did not test) to hit the board?” Possible answer: the same time it took for the other trials because changing ball mass did not change the time it took for the ball to hit the board. Try to make sure each student in your group answers one question.

Once the group understands of their experiment and findings, have them practice their poster presentation, making sure they are reading the poster parts in the correct order (scientists' names, question, experimental set-up, procedure, results graph, and results summary). Make sure each student's part is highlighted in their notebook. If students are reading from multiple pages, use a paperclip to clip these pages together to make it easier for them to flip back and forth. Remind students to read from their notebook rather than from their poster.

If there is additional time, tell the group, "Other students will ask you questions during your poster presentations. We should think about what questions you might be asked and then think of the answers to those questions so you will be prepared during your presentation."

Do not let poster practice go over 15 minutes.

Poster Presentations:

(41 minutes – Full Class – SciTrek Volunteers/SciTrek Lead)

Have students return to their original class seats. Ask the class, "What is the question we have been working on investigating?" Students should reply, "What variables affect ball motion?" Ask the class, "Why are we interested in answering this question?" Possible student response: if we can determine the variables that affect ball motion then we will be able to predict other types of motion. Tell students, "During the presentations, I will take notes, but you will have to help me by telling me the changing variable of the group after they say their question. I will also records the group's changing variable values, and the time." Turn to page 2 in the picture packet.

Tell students, "You will get the chance to ask scientific questions after the presentation. These questions are important, because you will have to summarize what you learned from the group so I can record it on the group notes. Therefore, your questions should focus on helping you be able to summarize the group's findings."

Volunteers should make sure that students are quiet, and respectful, when other groups are presenting. When your group is presenting, go to the front of the room with them; prompt students if they do not know who talks next, and remind them to read from their notebooks.

During the student question time, the lead and/or volunteers should ask at least one question. Examples of possible questions are: "How do you know...?" or "Is there anything else you can do to get more information about your question?" or "Can you predict what the time would be if you used (untested changing variable value)?" Each group should answer approximately five questions (one question per student).

When students are done asking questions, have them summarize what the group found. This is challenging for 3rd graders, therefore, you need to break it down into the following four questions 1) What was the group's changing variable? 2) (point to the notes where you recorded the values of the changing variable) What pattern do you see in the (insert changing variable)? 3) (point to the notes where you recorded the time) What pattern do you see in the time? 4) Can someone put what we learned into a sentence? If they are still having trouble, give them the sentence frame "As the (insert changing variable) (insert pattern) the time for the ball to hit the board (insert what happens)" Ex: As the run length get longer the time for the ball to hit the board gets longer. Once they have generated a summary, record this on the notes page.

An example filled out notes on presentations, is shown below.

| What variables affect ball motion? | | | | |
|--|------------------|------------------|------------------|------------------|
| Group 1 | | | | |
| Changing Variable: | | | | |
| Ramp height (cm) | 30 | 20 | 45 | 10 |
| Time for ball to hit board (s): | $1 \frac{2}{10}$ | $1 \frac{2}{10}$ | $1 \frac{2}{10}$ | $1 \frac{2}{10}$ |
| Summary: If a ramp is tall or short, the ball takes longer to hit the board. The ball takes less time if the ramp is mid-height. | | | | |
| Group 2 | | | | |
| Changing Variable: | | | | |
| Ball circumference (cm) | 24 | 30 | 18 | 33 |
| Time for ball to hit board (s): | $1 \frac{6}{10}$ | $1 \frac{6}{10}$ | $1 \frac{6}{10}$ | $1 \frac{2}{10}$ |
| Summary: Ball circumference does not affect the time it takes the ball to hit the board. | | | | |
| Group 3 | | | | |
| Changing Variable: | | | | |
| Ball Mass (g) | ~360 | ~100 | ~165 | ~305 |
| Time for ball to hit board (s): | $1 \frac{3}{10}$ | $1 \frac{3}{10}$ | $1 \frac{3}{10}$ | $1 \frac{4}{10}$ |
| Summary: Ball mass does not affect the time it takes the ball to hit the board. | | | | |
| Group 4 | | | | |
| Changing Variable: | | | | |
| Ball Mass (g) | ~165 | ~360 | ~265 | ~55 |
| Time for ball to hit board (s): | $1 \frac{6}{10}$ | $1 \frac{6}{10}$ | $1 \frac{2}{10}$ | $1 \frac{8}{10}$ |
| Summary: Agrees with previous group. | | | | |

Page 2, Picture Packet

2

After all poster presentations have been given, ask the class, “What did we learn about ball motion?” Have them summarize the class findings. The highlights from many experiments are shown below. Do not expect students to know highlights from experiments that were not run.

- The longer the *run length* the more time it takes for the ball to hit the board.
- As the *ramp height* gets taller (up to about 45°), the less time it takes for the ball to hit the board.
Note: If the ramp is above a 45° angle, then energy is lost when the ball hits the ground after coming off the ramp and the ball takes longer to hit the board.
- *Ramp length* does not affect the time it takes for the ball to hit the board.
- *Ball circumference* does not affect the time it takes for the ball to hit the board.
Note: The balls do have slightly different moments of inertia which would affect their speeds, however over the distance that the students are looking at usually this is not seen.
- *Ball mass* does not affect the time it takes for the ball to hit the board.

When summarizing experiments, use student-collected data and not what they should have found from the list above. Ask students, “What values of variables would you need to get a ball to hit the board at 200 cm in as little time as possible?”

- Run Material: Smooth material
- Ramp Length: Any length
- Ramp Height: 35 cm (for a ramp length of 50 cm this will give a 45° angle)
- Ball circumference: Any circumference
- Mass: Any mass

If no one in the class did experiments on one of the variables above, they will not know how that variable affects ball motion, and do not expect them to tell you which value to use. Tell students, “You have taught me a lot about ball motion.”

Wrap-Up:

(2 minutes – Full Class – SciTrek Lead)

Tell students, “The mentors who have been working with you are undergraduate, and graduate, students who volunteer their time so that you can do experiments. This is the last day you will see your volunteers, so we should say thank you, goodbye to them. I will come back and work with you one more day.

Have students remove the paper parts of their nametags (which they can keep) from the plastic holder and return the plastic holder to their volunteers.

Clean- Up:

1. Collect plastic nametag holders, and allow students to keep the paper part of their nametags.
2. Collect notebooks.
3. Leave posters in the classroom.
4. Place all other materials in your group box, and bring them back to UCSB.
5. If you will not be attending the tie to standards day, remove all materials from your lab coat pockets, remove your nametag, unroll your lab coat sleeves, and put your lab coat into the dirty clothes bag at UCSB.

Day 6: Question Assessment/Draw a Scientist/Tie to Standards/Content Assessment
Schedule:

Question Assessment (SciTrek Lead) – 10 minutes

Draw a Scientist (SciTrek Lead) – 5 minutes

Tie to Standards (SciTrek Lead) – 35 minutes

Content Assessment (SciTrek Lead) – 10 minutes

Materials:
Lead Box:

- | | | |
|--|--|---|
| <input type="checkbox"/> (3) Extra notebooks | <input type="checkbox"/> (25) Question assessments | <input type="checkbox"/> (2) Wet erase markers |
| <input type="checkbox"/> Notebooks | <input type="checkbox"/> (25) Draw a Scientist | <input type="checkbox"/> Teacher final survey QR code |
| <input type="checkbox"/> Lead instructions | <input type="checkbox"/> (25) Content assessments | <input type="checkbox"/> (2) Light blue balls (27 cm circ., ~265 g) |
| <input type="checkbox"/> Motion picture packet | <input type="checkbox"/> Time card | <input type="checkbox"/> Purple ball (27 cm circ., ~360 g) |
| <input type="checkbox"/> Lead lab coat | <input type="checkbox"/> (2) Pencils | |

Other Supplies:

- | | | |
|---|---|---|
| <input type="checkbox"/> 5 ft x 2 ft outdoor carpet with measurement mark | <input type="checkbox"/> Board (50cm × 30cm) with Astroturf | <input type="checkbox"/> Ball stop board (65 cm × 30 cm) |
| <input type="checkbox"/> 125 cm x 30 cm of Astroturf | <input type="checkbox"/> Board (100 cm × 30 cm) with marks on back side | <input type="checkbox"/> (2) Wood ramp holders (13 cm tall) |
| <input type="checkbox"/> (2) Boards (50cm × 30cm) with outdoor carpet | | <input type="checkbox"/> Wood ramp holder (22 cm tall) |

Notebook Pages:

I acted like a scientist when I measured how long it took the ball to hit the board.

TIE TO STANDARDS

- What two measurements do you need to get the speed of an object?
time and distance
- If all distances are equal, the ball that hits the board first has a (faster) (circle one) slower speed.

Ramp Height

- Fill out the following chart. Predict which set-up will cause the ball to hit the board first and circle your answer in the prediction column. For each of the trials write the set-up that hit the board first, or T if the two balls tied.

| Set-Up 1 | Set-Up 2 | Prediction | Data |
|--------------------|--------------------|--|--------------|
| | | Which set-up will cause the ball to hit the board first? (Circle One) | Trial 1 2 |
| Ramp Height: 13 cm | Ramp Height: 22 cm | 1 2 Tie | Trial 2 2 |
| | | | Trial 3 2 |

- Does the ramp height affect the speed of the ball? (YES) NO
- Explain how ramp height affects the speed of the ball.

The taller the ramp, the faster the ball hits the ground.

10

Ball Mass

- Fill out the following table with the same directions as question 3.

| Set-Up 3 | Set-Up 4 | Prediction | Data |
|-------------------|-------------------|--|----------------|
| | | Which set-up will cause the ball to hit the board first? (Circle One) | Trial 1 Tie |
| Ball Mass: ~265 g | Ball Mass: ~360 g | 3 4 <u>(Tie)</u> | Trial 2 Tie |
| | | | Trial 3 Tie |

- Does the ball mass affect the speed of the ball? YES (NO)
- Explain how the ball mass affects the speed of the ball.
Ball mass does not affect the speed of the ball.
- Which ball do you think will hit the wooden run first when dropped from the same height?
Blue Ball (~265 g) Purple Ball (~360 g) (The Balls will Tie)
- Which ball hit the ground first? the balls tied

Run Material

- Fill out the following table with the same directions as question 3.

| Set-Up 5 | Set-Up 6 | Prediction | Data |
|--------------------|--------------------|--|--------------|
| | | Which set-up will cause the ball to hit the board first? (Circle One) | Trial 1 6 |
| Run Material: Turf | Run Material: Wood | 5 <u>(6)</u> Tie | Trial 2 6 |
| | | | Trial 3 6 |

11

- Does the run material affect the speed of the ball? (YES) NO

- Explain how run material affects the speed of the ball.

The smoother the run material, the faster the ball.

Is motion predictable?

- Circle the values below that would cause a ball to travel at the **fastest speed**. If the variable does not affect the speed of the ball, then circle either. Assume a ramp length of 50 cm and a run length of 150 cm.

| Variable | Option 1 | Option 2 | Option 3 |
|---------------|------------|------------------|-----------------|
| Ramp Height: | | | Either |
| Ball Mass: | 100 g | 1,000 g | <u>(Either)</u> |
| Run Material: | Sand Paper | <u>(Plastic)</u> | Either |

- Circle the values below that would cause a ball to travel at the **slowest speed**. If the variable does not affect the speed of the ball, then circle either. Assume a ramp length of 50 cm and a run length of 150 cm.

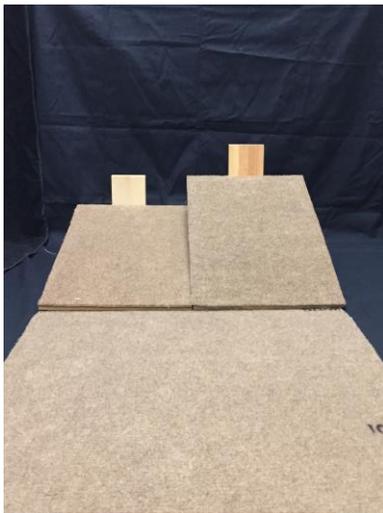
| Variable | Option 1 | Option 2 | Option 3 |
|---------------|---------------------|------------|-----------------|
| Ramp Height: | <u>(Small ramp)</u> | | Either |
| Ball Mass: | 1 g | 10 g | <u>(Either)</u> |
| Run Material: | <u>(Tar)</u> | Card board | Either |

12

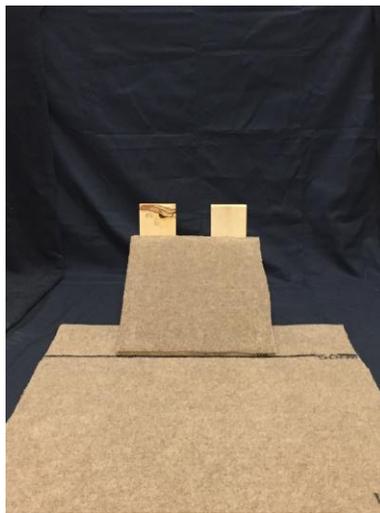
Preparation:

SciTrek Lead:

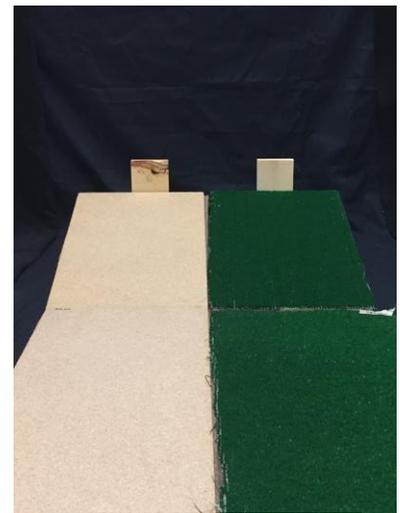
1. If the teacher is not leading the tie to standards activity, do the following:
 - a. Ask the teacher if they completed the SciTrek final survey. If not, give them the QR code from the lead box, and ask them to go to the website (at a later time), and fill out the evaluation of the program.
 - b. Give the teacher an extra notebook, and have them fill it out with their students to follow along.
 - c. Collect the teacher's lab coat, and put it in the lead box.
2. If you are a teacher and did not complete the SciTrek final survey, take the QR code from the lead box and fill out the evaluation of the program, at a later time.
3. Pass out the question assessment and notebooks to students or get the classroom teacher to pass them out.
4. Set up the document camera for the tie to standards activity (pages 10-12, notebook).
5. Assemble the tie to standards set up (seen in picture below as well as on page 3 of the picture packet).
 - a. Roll out the 5 ft × 2 ft carpet onto a table in the front of the class (if it is not possible to do this on a table then it can be done on the floor, see floor set-up note below).
 - b. Set up two 50 cm × 30 cm outdoor carpet covered ramps on the two different wood ramp holders (heights 13 cm tall and 22 cm tall).
 - c. Align the ramps so the bottom of the ramps are sitting on the 50 cm mark on the carpet.
 - d. Set the ball stop board at the 150 cm mark (Set-Up 1).
 - e. Have the rest of the tie to standards materials close (purple ball, 2 light blue balls, additional 13 cm tall wood ramp holder, board with Astroturf, wood board 100 cm, and Astroturf).
6. Put your lab coat in the lead box, at the end of the day.



Set-Up 1



Set-Up 2



Set-Up 3

Floor Set-Up Note:

If you must set up on the floor, after you have the students make their first prediction (testing the ramp height) you need to warn the students about all the moving that will take place during today's session. Give students the following instructions: "On the count of three, I want everyone to stand up and move around the carpet set-up so you are able to see our experiment. The people in the front must sit so those behind them can see. I will make sure everyone is able to see before I start the trials, but remember the quicker and quieter you all get set, the sooner we will be able

to see each experiment. In addition, when you get to the carpet set-up make sure not to touch it. Let's see how we do. One... two... three." The first time, you may need to direct students whether they need to sit, kneel, or stand. After each experiment have students return to their seats. Tell students, "We will repeat this process two more times during the session."

SciTrek Volunteers:

Help the lead change out the ramps during the activity. Once the lead is done testing ramp height with the class remove one of the 50 cm ramps and the 22 cm ramp holder. Place a second 13 cm ramp holder under the 50 cm ramp that is left. This will be used for testing ball mass (Set-Up 2). Once the lead is done testing ball mass, place the Astroturf over the outdoor carpet on half of the set-up and place the 100 cm ramp wood side up on the other half of the set up. Then replace one of the ramps with an Astroturf ramp. The wooden ramp is the outdoor carpet ramp turned over (Set-Up 3).

Question Assessment:

(10 minutes – Full Class – SciTrek Lead)

"Before we start our activity today, we will determine how your ideas on testable questions are developing." Have students write their name, teacher's name, and date at the top of the assessment. Tell students, "When doing this assessment, you should work individually so there should be no talking." As you are giving the assessment, walk around the room and verify students have written their name on their paper.

Read the instructions to the students. Then, read each of the questions and tell students to circle 'testable' for questions that science can answer or 'not testable' for questions that science cannot answer.

Have student turn over the paper and answer question 11 and 12 which has them write an example of a testable question and revise a question that is not testable to be testable. When students are finished have them turn over their paper.

Then, have the students answer the question 13 *what is one thing a scientist does other than experiments?*

Question 14 asks students if they like science more, less, or the same after going through the SciTrek Program. Tell students, "For question 15, you are going to tell me how much you feel like a scientist. This is an opinion question and has no right answer, therefore you should be totally honest." Show them the circles on the far left and tell them, "If you don't identify as a scientist at all, you should circle these circles." Show them the circles on the far right. Tell them, "If you feel like you are a scientist and do a lot of things that scientists do, you should circle these circles. If you feel somewhere in the middle, you should circle one of the options in the middle." Question 16 asks students whether or not they would like to get a job as a scientist, have them circle either yes, maybe, or no. Questions 17-122 ask about students' interests in various school subjects. Have them circle either very interesting, interesting, not interesting, or boring, for each. When students are finished, collect the assessments, and verify the student's names are on the top of the assessments.

Draw a Scientist:

(5 minutes – Full Class – SciTrek Lead)

Pass out the draw a scientist paper. Have students write their name, teacher's name, and date on the top of the assessment. Give students **exactly 4 minutes** to draw a picture of a scientist. Once they are done,

ask them to write on the bottom line who they drew a picture of. If it was no one specific, they can leave the line blank. Then collect the papers from students, verifying their names are on the top of the papers.

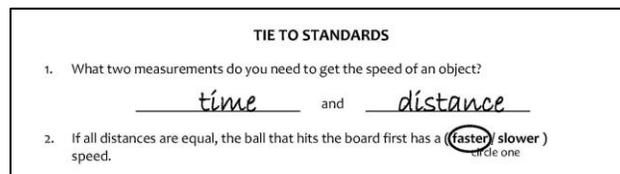
Tie to Standards:

(35 minutes – Full Class – SciTrek Lead)

Tell the class, “I have enjoyed your poster presentations the last time I was here and today we are going to revisit some of the variables that affected ball motion.” Have students turn to page 10 of their notebooks. Place the class notebook under the document camera and turn to page 10.

Speed vs. Time (4 minutes)

Ask students, “What did you measure during your experiments?” Possible student response: we were measuring the time it took for the ball to hit the ball stop board, which was a set distance from the top of the ramp. Tell students, “I heard some of you talking about ball speeds during the module and I was wondering what you meant by this because it seems like you only measured the time. Therefore, how would you be able to tell anything about speed?” By the end of the conversation, make sure students understand to get a speed they need to measure time and distance. If students have trouble generating time and distance ask them, “Would it be fair to have two students race, one running one lap around the school and the other running ten laps around the school? Which of these students would finish the race first and why?” Students should be able to determine the student running one lap will finish in a shorter time than the student running ten laps but this does not mean the student running one lap ran faster. Therefore, in order to accurately determine speed, they need both time and distance. Since both time and distance were measured during their experiments they can talk about the speeds of the balls. Have students fill in questions 1 and 2 on page 10. See example below.



Effects of Ramp Height (8 minutes)

Show students the set-up on the table. Tell students, “I am going to roll two balls that have the same circumference (27 cm) and mass (~265 g) down the two ramps which are 13 cm tall and 22 cm tall. I will then allow the balls to roll for 150 cm before the balls will hit the ball stop board. Before I do this experiment, I want you to predict what you think will happen and record this prediction in your notebook for question 3.” Allow students time to make their predictions and then have one student share what they think and why. After, have the rest of the class vote if they agree/disagree with the student’s prediction using thumbs up/thumbs down.

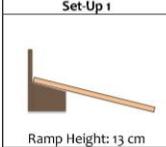
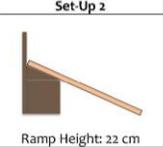
Set the two light blue balls at the top of the ramps and release the balls at the same time. In the “trials” column of question 3 record which set-up made the ball hit the board first. Fill in the result of trial 1 on the class notebook under the document camera. Repeat the process two more times for trials 2 and 3.

Ask students, “Did the ramp height affect the time it took the ball to hit the board?” Students should reply, “Yes.” Have the students circle *yes* for question 4. Have a few students summarize the relationship between ramp height and the time it takes for a ball to hit the board. Write one of these sentences in the class notebook and have students copy it into their notebook. See example student work below.

IMPORTANT: If there is no SciTrek volunteer in the room, as students are writing about how ramp height affects the speed, remove the 22 cm ramp holder and one of the 50 cm ramps. Place a second 13 cm ramp holder under the 50 cm ramp that is left (Set-Up 2).

Ramp Height

3. Fill out the following chart. Predict which set-up will cause the ball to hit the board first and circle your answer in the prediction column. For each of the trials write the set-up that hit the board first, or T if the two balls tied.

| Set-Up 1 | Set-Up 2 | Prediction | Data |
|---|---|--|--------------|
|  |  | Which set-up will cause the ball to hit the board first? (Circle one) | Trial 1 2 |
| Ramp Height: 13 cm | Ramp Height: 22 cm | 1 2 Tie | Trial 2 2 |
| 4. Does the ramp height affect the speed of the ball? | | <input checked="" type="radio"/> YES | NO |
| 5. Explain how ramp height affects the speed of the ball. <u>The taller the ramp, the faster the ball hits the ground.</u> | | | |

Ask students, “Do you think that the taller ramp will always result in the ball hitting the board faster?” If a group explored ramp height as a changing variable they might have found that increasing the ramp height decreases the time it takes for the ball to hit the ball stop board, until the ramp has an angle of $\sim 45^\circ$ (for the 50 cm ramp length, 45° occurs when the ramp height is 35 cm). Anything greater than this angle, increases the time it takes for the ball to hit the ball stop board. (If this variable was not investigated by a group take one of the ramps and increase the ramp height until the ramp is at a 90° from the run. Ask students, “Will the ball reach the ball stop board slower or faster than the other ramp that is set-up?” Students should predict that when the ramp is at 90° , the ball will never reach the ball stop board. Therefore, if the ramp gets too steep the time it takes to reach the ball stop board increases.) Ask the class, “Why does it take more time for the ball to hit the ball stop board when the board is vertical or almost vertical?” By the end of the conversation make sure that students understand that the taller the ramp, the more energy the ball has. However, more of the ball’s energy is directed in the downward direction (z direction), therefore, less of the energy is directed along the ramp (x direction). (In other words, the fall causes the ball to transfer a significant amount of energy into the table; therefore, the ball does not travel as far. The extreme of this is shown when the ramp is at 90° and the ball does not travel in the x direction.)

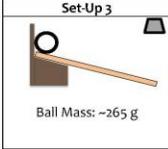
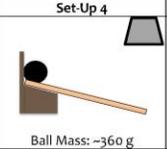
Effects of Ball Mass (10 minutes)

Tell students, “I am going to roll two different balls down a ramp that is 13 cm off the ground. One of the balls has a mass of ~ 265 g (light blue ball) and the other ball has a mass of ~ 360 g (purple ball) and both balls have the same circumference (27 cm). The balls will roll for 150 cm before the balls will hit the ball stop board. Before I do this experiment, I want you to predict what you think will happen and record this prediction in your notebook for question 6.” Allow students time to make their predictions and then have one student share what they think and why. After, have the rest of the class vote if they agree/disagree with the student’s prediction using thumbs up/thumbs down.

Set the two balls at the top of the same 13 cm outdoor carpeted ramp, each against their own ramp holder, and release the balls at the same time. In the *trials* column of question 6 record which set-up made the ball hit the ball stop board first. Fill in the result of trial 1 on the class notebook under the document camera. Repeat the process two more times for trials 2 and 3. If students are having a hard time agreeing that the balls have tied, ask them, “If the balls tie, should you hear one hit or two hits when the balls hit the board?” Students should reply, “one hit.” Tell students, “If the balls do not tie then they will hear two hits.” Have the students close their eyes and listen to what happens.

Ball Mass

6. Fill out the following table with the same directions as question 3.

| Set-Up 3 | Set-Up 4 | Prediction | Data |
|---|---|--|----------------|
|  |  | Which set-up will cause the ball to hit the board first? (Circle One) | Trial 1 Tie |
| | | 3 | Trial 2 Tie |
| | | 4 | Trial 3 Tie |
| | | <input checked="" type="radio"/> Tie | |

7. Does the ball mass affect the speed of the ball? YES NO

8. Explain how the ball mass affects the speed of the ball.
Ball mass does not affect the speed of the ball.

9. Which ball do you think will hit the wooden run first when dropped from the same height?

Blue Ball (~265 g) Purple Ball (~360 g) The Balls will Tie

10. Which ball hit the ground first? the balls tied

Ask students, “Does ball mass affects the time the ball takes to hit the board?” Students should reply, “No.” Have students circle *no* for question 7. Have a few students summarize the relationship between ball mass and the time it takes for a ball to hit the board. Write one of these sentences in the class notebook and have students copy it into their notebook. See example student work above.

IMPORTANT: If there is no SciTrek volunteer in the room, as students are writing about how ball mass affects the speed, place the Astroturf over the outdoor carpet on half of the set-up and place the 100 cm ramp, wood side up, on the other half of the set up. Then replace one of the ramps with an Astroturf ramp. For the wooden ramp, turn the outdoor carpet ramp over (Set-Up 3).

Tell students, “I am now going to drop the light blue and purple balls onto the wooden run. Which ball do you with will hit first?” Have students circle their prediction for question 9. Have one student share what they think and why. Then have the rest of the class vote if they agree/disagree with the student’s prediction using thumbs up/thumbs down. Hold one ball in each hand, and make sure that the balls are at the same height. Drop the balls at the same time onto the wooden run so students can hear the balls hit. Students will observe that the balls will hit the run at the same time. Have them record this for question 10. Ask students, “How does ball mass affect both rolling balls down a ramp and dropping balls?” Students should realize the mass does not affect the speed the ball travels in either of the two cases.

Note: If a feather and a BB (ammo pellet) were dropped at the same time from the same height the BB would hit the ground first. This is not because the BB is heavier than the feather. This is because the feather is larger and encounters more air resistance. If the feather and the BB were dropped at the same time from the same height in a vacuum (where there is no air, and no air resistance) both would hit the ground at the same time.

Effect of Run Material (8 minutes)

Tell students, “I am going to roll two balls that have the same circumference (27 cm) and mass (250 g) down the ramps/runs that are made of different materials. One run will be made out of wood and the other run will be made out of Astroturf. Both ramps will have a height of 13 cm. I will then allow the balls to roll for 150 cm before the ball will hit the ball stop board. But before I do this experiment, I want you to predict what you think will happen and record this prediction in your notebook for question 11.” Allow students time to make their predictions and then have one student share what they think and why. After, have the rest of the class vote if they agree/disagree with the student’s prediction using thumbs up/thumbs down.

Set the two balls at the top of the ramps and release the balls at the same time. In the *trials* column of question 11, record which set-up made the ball hit the ball stop board first. Fill in the result of trial 1 on the class notebook under the document camera. Repeat the process two more times for trials 2 and 3.

Ask students, “Does run material affects the time the ball takes to hit the board?” Students should reply, “Yes.” Have the students circle *yes* for question 12. Have a few students summarize the relationship between run material and the time it takes for a ball to hit the board. Write one of these sentences in the class notebook and have students copy it into their notebook. See example student work below.

Run Material

11. Fill out the following table with the same directions as question 3.

| Set-Up 5 | Set-Up 6 | Prediction | Data |
|---|---|--|--------------|
|  Run Material: Turf |  Run Material: Wood | Which set-up will cause the ball to hit the board first? (Circle One) | Trial 1 6 |
| | | 5 | Trial 2 6 |
| | | 6 | Trial 3 6 |
| | | Tie | |

12. Does the run material affect the speed of the ball? YES NO

13. Explain how run material affects the speed of the ball.

The smoother the run material, the faster the ball.

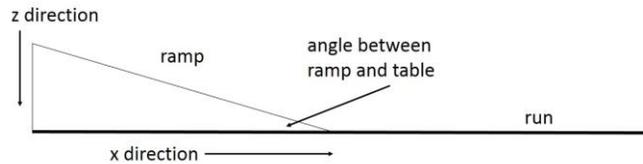
Explain to students the material objects travel over has a large effect on the motion of the object. The smoother the run material, the faster an object will move. The resistance the object encounters when moving is called friction. Have the students rub their hands together and ask them, “What do you feel?” Students should reply, “Heat.” This feeling is also because of friction. Tell students, “Even when a ball is thrown through the air it encounters friction from the particles like nitrogen in the air (air resistance). This is why eventually a thrown object will fall to the ground. (**Note:** Gravity also plays a role, but the ball would travel much farther if there was no air resistance/friction). Ask students, “Would there be friction if a ball was thrown in outer space?” Possible student response: there is no air in outer space so there would not be friction (no air resistance). Ask students, “What would happen if a ball was thrown in outer space?” Allow students to share their thoughts and by the end of the conversation make sure students understand that if a ball was through in outer space the ball would just keep going in the direction you throw it forever because there would be nothing to slow it down.

Teacher/Lead Note: Effect of Ramp Length

Only address ramp length if a student asks a question about the effects of ramp length. This variable is the hardest for students to understand and is contrary to what simple Newtonian physics predicts.

In theory, ramp length should not affect the time it takes for the ball to hit the ball stop board or the speed of the ball. The stored energy of the ball only depends on the original height and mass of the ball. Since the same ball was used for all the trials (therefore the mass of the ball is the same) and the ball started at the same height, all trials should have the same amount of stored energy. Since they all have the same amount of stored energy, the ball should have the same final speed for all trials. However, experimentally students will see the balls hit the stop board in slightly different amounts of time. They will find that the smaller the angle between the tabletop and the ramp, (resulting in a less steep slope) the faster the ball will travel (the sooner it will hit the ball stop board). When a ball is released from the top of the ramp the ball has velocity in the z (downward) and x (direction towards the run) directions. The steeper the ramp, the larger the z component of the velocity and the smaller the x component of the velocity. As the ball comes off the ramp and hits the run, if the z component of the velocity is large, the

ball hits the run more forcefully and transfers a large percentage of its energy into the run. This energy is no longer available to propel the ball down the run. The extreme of this phenomenon can be easily observed if the ramp is at a 90° angle. When the ball is released the ball falls and hits the run and essentially does not roll down the run.



Motion Predictability (5 minutes)

Ask students, “Do you think that ball motion is predictable, and why?” Have a few students share their answers with the class. Tell students, “I want to design a set-up in which the ball travels as fast as possible.” Ask students, “Does this mean that the ball would hit the ball stop board in more or less time?” Students should reply, “Less.” Tell students, “When designing this set-up there are only a few variables we can choose from and I need your help to identify the variables that we should use.” Have students individually go through the variables in question 14(a) and circle each value that they think would allow the ball to travel the fastest. After they have filled out the question, have one student share each variable that they chose and ask the class if they agree/disagree with thumbs up/thumbs down. An example of student work can be seen below.

Repeat the above procedure for question 14(b), however this time, students need to determine the variable that would allow the ball to travel the slowest. An example of student work can be seen below.

Is motion predictable?

14. Circle the values below that would cause a ball to travel at the **fastest speed**. If the variable does not affect the speed of the ball, then circle either. Assume a ramp length of 50 cm and a run length of 150 cm.

| Variable | Option 1 | Option 2 | Option 3 |
|---------------|------------|----------|----------|
| Ramp Height: | | | Either |
| Ball Mass: | 100 g | 1,000 g | Either |
| Run Material: | Sand Paper | Plastic | Either |

15. Circle the values below that would cause a ball to travel at the **slowest speed**. If the variable does not affect the speed of the ball, then circle either. Assume a ramp length of 50 cm and a run length of 150 cm.

| Variable | Option 1 | Option 2 | Option 3 |
|---------------|----------|------------|----------|
| Ramp Height: | | | Either |
| Ball Mass: | 1 g | 10 g | Either |
| Run Material: | Tar | Card board | Either |

Tell students, “I have enjoyed working with you and I have learned a lot about ball motion from you. I now know motion is predictable, and the ball mass does not affect the speed of the ball but ramp height, ball circumference, and run material will affect the speed. Before I leave, I would like to see how your science content knowledge has changed.”

Content Assessment:

(10 minutes – Full Class – SciTrek Lead)

Have students close their notebooks and place them in the corner of their desk. Pass out the content assessment to students. Have students write their name, teacher’s name, and date on the top of their paper. During the assessment, remind students to work by individually. Read each of the content questions to students, and have them select/fill out the correct answer. When students are finished, collect the assessments, and verify they have written their names on the assessments.

Tell students, “You can keep your notebooks. I have enjoyed working and learning with you, and I hope you continue to see yourselves as scientists, and explore the world around you.”

Clean- Up:

1. Leave notebooks with students.
2. Place all other materials in your lead box, and bring them back to UCSB.
3. Remove all materials from your lab coat pockets, remove your nametag, unroll your lab coat sleeves, and put your lab coat into the dirty clothes bag at UCSB.

Extra Practice Solutions:

EXTRA PRACTICE
Questions

Circle TESTABLE if the question can be tested by science. Circle NOT TESTABLE if the question cannot be tested by science. If the question is NOT TESTABLE change (revise) the question to be something that is testable.

1. How much time does it take to walk three miles? Testable Not Testable
Revision: _____?
2. Is a bird loud? Testable Not Testable
Revision: What species of bird chirps the loudest _____?
3. Is drinking eight glasses of water a day a good idea? Testable Not Testable
Revision: How many ml of water do people drink in a day?
4. How many songs does the radio station play in one hour? Testable Not Testable
Revision: _____?
5. Which type of juice is the most refreshing? Testable Not Testable
Revision: How many apples are used to make a glass of juice?
6. Do bees land on bright colored flowers? Testable Not Testable
Revision: _____?
7. Is ice cream more delicious than cookies? Testable Not Testable
Revision: Which has more sugar: ice cream or a cookie _____?

13