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. Some 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 testable 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: Procedure/Results Table/Technique/Experiment (60 minutes)
Day 4: Graph/Results Summary/Poster Making (60 minutes)
Day 5: Poster Presentations (60 minutes)
Day 6: Question Assessment/Tie to Standards/Content Assessment (60 minutes)

The exact module dates and times are posted on the SciTrek website (http://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 1105). Thirty minutes are allotted for transportation before and after the module, therefore, if a module was running from 10-11 then the module times on the website would be from 9:30-11:30.

Student Groups:

Students are divided into four groups of ~five students each for the entire module. One volunteer is assigned to help each group. We find these 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 a parts of size \( \frac{1}{b} \).
Learning Objectives:

1. Students will know that an object’s motion is predictable and can 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.
5. Students will be able to suggest revisions for questions that are not testable in order to make them testable.
6. Students will be able to list at least one way that they behaved 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 ~five students.

1. Module 1 & 2 (year 1)
   a. Classroom Teacher Leads a Group

2. Module 3 & 4 (year 2)
   a. Classroom Teacher Co-Leads the Class (an experienced SciTrek volunteer will be present to help out if needed)
      i. Classroom teacher will be responsible for leading entire class discussions (examples: question activity, tie to standards, etc.).
      ii. Classroom teacher will be responsible for time management.
      iii. Classroom teacher will be responsible for overseeing volunteers and helping any groups that are struggling.
      iv. Classroom teacher will be responsible for all above activities, the SciTrek co-lead will only step in for emergencies.

3. Any Additional Modules (year 3 and beyond)
   a. Classroom Teacher Leads the Class
      i. Classroom teacher will be responsible for leading entire class discussions (examples: question activity, tie to standards, etc.).
      ii. Classroom teacher will be responsible for time management.
      iii. Classroom teacher will be responsible for overseeing volunteers and helping any groups that are struggling.

SciTrek staff will be 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 scitrekadmin@chem.ucsb.edu to learn more.
In addition, teachers are required to come to UCSB for the module orientation, ~one week prior to the start of the module. Contact scitrekadmin@chem.ucsb.edu for exact times and dates, or see our website at http://www.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 that 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 do an orientation for the module will result in loss of priority registration for next 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 the SciTrek staff at orientation.

Days 1 and 3:

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

Days 2, 3, and 4:

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

Days 5 and 6:

Have the 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 (~one week before your module, exact orientation times are found at: http://www.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 discussion

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 do 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 discussion 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 appropriate 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) 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 back 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

**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:
  - □ Student nametags
  - □ (7) Student notebooks
  - □ Volunteer instructions
  - □ Picture of experimental set-up
  - □ Volunteer lab coat
  - □ (2) Pencils
  - □ (2) Wet erase markers
  - □ Ruler
  - □ (7) Timers
  - □ (2) Wood ramp holders (13 cm tall)
  - □ (2) Green balls (27 cm circ., ~200 g)
  - □ Measuring tape (152 cm)
  - □ Measuring tape (300 cm)
  - □ Large binder clip

- Other Supplies:
  - □ (4) Large group notepads
  - □ (4) 6 ft x 2 ft carpet
  - □ Box with 4 electronic scales
  - □ (4) Ball stop boards (65 cm x 30 cm)
  - □ (4) Boards (50 cm x 30 cm) with outdoor carpet
  - □ (4) Boards (50 cm x 30 cm) with shag carpet
  - □ (4) Pieces of shag carpet (30 cm x 100 cm)
Lead Box:
- (3) Blank nametags
- (3) Extra student notebooks
- Lead instructions
- Motion picture packet
- Picture of experimental setup
- Lead lab coat

- (25) Question assessments
- Time card
- (2) Pencils
- (2) Wet erase markers
- (4) Markers (purple, green, blue, orange)
- Ruler
- (4) Timers
- (2) Green balls (27 cm circ., ~200 g)
- Measuring tape (152 cm)
- Measuring tape (300 cm)
- Large binder clip

**Notebook Page, Notepad Pages, and Picture Packet Page:** (Note: Notebook and picture packet pages are rectangular and filled out in black, notepad pages are squarer and filled out in blue, and picture pack pages are rectangular and filled out in blue.)

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**TECHNIQUE**

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:

- 1:12:21

  - Hours
  - Minutes
  - Seconds

  The above timer has gone for 1 hour, 12 minutes, 21 seconds and \( \frac{7}{10} \) fraction of a second.

1. If \( 5:00:45 \) is seen on your timer how much time has passed?
   - Hours: 5
   - Minutes: 0
   - Seconds: 45
   - Fraction of a Second: \( \frac{7}{10} \)

2. If \( 0:00:30 \) is seen on your timer how much time has passed?
   - Hours: 0
   - Minutes: 0
   - Seconds: 30
   - Fraction of a Second: \( \frac{7}{10} \)

#### How to use a timer:

1. If timer is off, push the blue button to turn it on.
2. If you do not see \( 0:00:00 \) then push the blue button again to reset the timer.
3. To start the timer push the yellow button.
4. To stop the timer push the yellow button again.
5. Record time to the nearest fraction of a second.
6. Ex: 0:00:25 would be recorded as \( \frac{7}{10} \) s.
7. To reset to \( 0:00:00 \), push the blue button.
8. Repeat.

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

1. How long does it take the SciTrek lead to unsnap/snap their lab coat? 2 \( \frac{7}{10} \) s
2. How long does it take the SciTrek leader to jump three times? 1 \( \frac{5}{10} \) s

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**OBSERVATIONS**

- 2 ramps - one covered in shag carpet and one covered in outdoor carpet
- Ball circumference = 27 cm
- Ball height = 15 cm
- Ball mass = 200 g
- Ruler
- Timer
- Plastic wall (green)
- The second board is 100 cm from the top of the ramp

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Teacher: Ms. O'Neill
Volunteer: Liz
Color: Blue
Set-Up:

SciTrek Lead:
If the classroom has a document camera, ask the teacher to use it for the technique activity (page 2, student notebook) and to record the group data (page 1, picture packet). If the classroom does not have a document camera, then tape the example poster-size notebook page and group data chart to the front board during the technique activity and observation discussion.
On the board, write the four group colors (orange, blue, green, and purple) and the name(s) of the volunteer(s) that will be working with each group.

SciTrek Volunteer:
Put your name, the teacher’s name, and your group color on the top of your group notepad.

As students are taking the question assessment, walk around the room and quietly place the students’ nametags, which are in your group box, on each student’s desk.

Have SciTrek notebooks and timers available to pass-out after students complete their assessment.

Once you have passed out the nametags, assemble the experimental set-up (seen in picture below as well as in the experimental set-up picture in your group box) on a spot on the floor where ~five students can sit. Use the following steps to help you with the set-up:
1. Roll out the outdoor carpet.
2. Place the piece of shag carpet so that it covers half of the run.
3. Set-up the outdoor carpet ramp in front of the outdoor carpet section of the run.
4. Set-up the shag carpet ramp in front of the shag carpet section of the run.
5. Put the wood ramp holders under each of the ramps to give the ramps a slope.
6. Make sure the wood ramp holders are as far under the ramps as they can go.
7. Attach the 300 cm measuring tape with the binder clip on the top of the shag carpet ramp and extend the measuring tape to the end of the run.
8. Set the ball stop board (65 cm x 30 cm) at the 100 cm mark on the measuring tape.
9. Set the timers, 152 cm measuring tape, scale, ruler, and one of the green balls on the set-up.
10. Hide the second green ball in your lab coat pocket until the end of the observations.

Introduction:
(2 minutes – Full Class – SciTrek 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.”
If you are a teacher that is leading the class tell your students that they are going to start a long-term science investigation and you have asked some scientists from UCSB to come and help. Allow the UCSB volunteers to introduce themselves and share their majors.

**Question Assessment:**
*(5 minutes – Full Class – SciTrek Lead)*

As the students are taking the assessment, the volunteers should get the student nametags out of their group boxes and walk around the room locating their students. Have the volunteers quietly lay each student’s nametag on their desk. If students do not have their name on their paper remind them to do so. After volunteers have handed out the nametags they should assemble the experimental set-up.

“Before we start with the module we will determine how your ideas on testable questions are developing.” Pass-out the question assessment and tell students to fill out their name, teacher’s name, and date at the top of the assessment. Remind the students that it is important that they fill out this assessment on their own.

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. When students are finished, collect the assessments and verify that the students’ names are on the top of the papers.

**Technique:**
*(10 minutes – Full Class – SciTrek Lead)*

As soon as students complete the question assessment, volunteers should pass-out a SciTrek 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 (volunteer’s names should be written on the board next to the group color they will be working with) on the front cover of their notebook. If a student does not have a nametag, only have them fill out their name and teacher’s name on the cover of their SciTrek notebook. They will be placed in a group when the class gets into groups for observations and they can fill out their group color and volunteer at that point.

Tell the class that for this module we are going to roll balls down ramps to try to answer the question, “What variables affect ball motion?” Ask the students, “Why do you think scientists would investigate this question?” By the end of the conversation, make sure that students understand that if we can find patterns in ball motion, this means that motion is predictable and we can predict future ball motion. Tell students that in order to do this, 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 blank notebook under the document camera. Tell students that for this experiment it is very important that their measurements of time are precise so that we can tell exactly how long it takes the ball to hit a board at a given distance for each of their trials.
Go over how to read the timer using the diagram. Tell students that the first number, before the colon, tells the amount of hours for which the timer has run. Ask the students, “How many hours did the top timer run?” Students should answer 1 hour. Tell students that the next number, between the colon and the apostrophe, is the amount of minutes for which the timer has run. Ask the students, “How many minutes did the top timer run?” Students should answer 12 minutes. Tell students that the next number, between the apostrophe and the quote, is the amount of seconds for which the timer has run. Ask the students, “How many seconds did the top timer run?” Students should answer 23 seconds. Tell students the last number (the small number) shows the parts of seconds. Ask the class if we know a way to record numbers that are a part of a whole. They should respond that we can record parts of whole numbers using fractions. Tell the students that the parts of a second go up to 10. Ask the students what the bottom number, or the denominator, should be for this fraction. Students should answer that 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 the students how we should record the parts of seconds for the example timer. They should say that the 7 parts on the timer should be put into a fraction over 10, giving them $\frac{7}{10}$. Tell students they will now fill out questions 1 and 2 on their own and then go over it as a class.

Have students go through numbers 1 and 2 on their own. Walk around to help the students who need help. 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 example notebook. Record the following:

1. 3 hours, 0 minutes, and 45 $\frac{3}{10}$ seconds
2. 0 hours, 1 minute, and 7 $\frac{1}{10}$ seconds
Tell students that now that they know how to read a timer, they 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.

1) If the timer is off, push the blue button to turn it on.
2) If you do not see 00:00’00” then push the blue button again to reset the timer.
3) To start the timer, push the yellow button.
4) To stop the timer, push the yellow button again.
5) Record the time to the nearest tenth of a second. Ex: 00:12’58” would be recorded as 12 \( \frac{8}{10} \) s.
6) To reset to 00:00’00”, push the blue button.
7) Repeat.

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

Tell students that they will now time two different activities. For the next two activities have a volunteer time the processes with the students so that students can have a number to compare their time to. For the first activity, they will record the amount of time it takes someone (either you or a SciTrek volunteer) to unsnap and snap their lab coat. Count them down to the start by saying “3…2…1…Go.” They should start their timers when you say go. They should stop the 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 the students check their time with the SciTrek volunteer’s time. Students should be able to get within one second of the volunteer’s time.

For the second practice activity, the students will record how long it takes you (or a SciTrek volunteer) to jump three times. Warn them that you are a good jumper so this will go very quickly so they need to pay close attention. They will start timing when you say go and they will stop timing the second your feet hit the ground on the third jump. Make sure that all students 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 the students check their time with the SciTrek volunteer’s time. Students should be able to get within \( \frac{4}{10} \) of a second of the volunteer’s time.

Tell students that now that they know how to use a timer they will be able to use this skill to help them make observations.

**Observation Discussion:**

*(2 minutes – Full Class – SciTrek Lead)*

Tell the students that scientists make many observations. Ask the class, “What is an observation? What are the types of things that you can record for an observation?” If they have trouble, show them an object and let them make some observations. Turn these specific observations into general features of an observation. Examples of possible general observations are: color, texture, size, weight, temperature, material, etc.

“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 they will now get in their groups and make observations. To determine their group, they will need to look at the color of their nametag (orange, blue, green, or purple). Tell each colored group where to go and to bring the timer, a pencil, and their notebook.
If a student does not have a nametag, identify the group with the least number of students in it and write the student’s name on one of the extra nametags that are in the lead box using that color of marker.

**Observations:**
(15 minutes – Groups – SciTrek Volunteers)

Once the students come over to your group, have them sit in boy/girl fashion and collect their timers and notebooks. Put the notebooks in the group box; students will not need these until the next SciTrek visit. Put out three timers, and verify that the floor is set up as described in the set-up section.

As a group, have the students generate observations about the experimental set-up before you start rolling the ball down the ramp. This should take you no longer than 10 minutes. Observations should be recorded on page 1 of the group 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. An example group notepad is seen below (left).

Pass-out a timer to three students. MAKE SURE THAT ONLY 3 STUDENTS ARE TIMING AND THAT YOU ONLY DO THE TRIAL ONCE. Tell the other students that they 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 to stop the timer when they both see and hear the ball hit the board. Count down by saying “3…2…1…Go” and release the ball. On the group notepad, ONLY record the three times the students measure as well as other observations about the shag carpet. Remember to record the partial seconds in a fraction of 10. Do not have them put the times in order or find the median. 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 then releasing 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. Students should say that the shag carpet run took longer than the outdoor carpet run. Ask students if there is 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.

As soon as your group has finished making observations of the two trials, go to the document camera and record the median measurement (middle measurement) of each trial on the class data sheet (page 1, picture packet). This should be done by you (the volunteer) and not the students.

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

An example group notepad is seen below (right); feel free to deviate from the example. Students do not need to record their observations into their notebooks.
Reproducibility Discussion:

(8 minutes – Full Class – SciTrek Lead)

Have the students look at the class data sheet (page 1, picture packet) seen below. Ask the students if every group got the same results. The students should respond “No.” Ask the groups if they all ran the same experiment. Have students tell you what experiment they carried out as well as what they measured/recorded in their groups. They should all realize that they did the same experiment. Ask the students why different groups got different numbers. Some possible responses might be: 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 that scientists often perform multiple trials 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 of the numbers they measured.

Ask the class what number they would pick if they had to pick one data point to represent the entire data set. 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 the students that they are going to find the median number in each set of numbers. Starting with the run on the shag carpet, have the students rearrange the numbers so that they are in increasing order. Then, have the 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 the students what we learned about ball motion from this experiment. Students should be able to tell you that the run material affects ball motion and that the smoother the surface, the shorter the time it takes for the ball to hit the board (faster the ball travels). Ask students to predict one surface that would be faster than outdoor carpet (example: smooth plastic) and one surface that would be slower than shag carpet (example: even longer 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.

Ask the students the following questions:

What does the word “variable” mean to a scientist?
Variables are 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 that there are other variables that will affect ball motion?
(multiple variables might affect ball motion)

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

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

Example: Variable: ramp height

Why might this variable affect ball motion? The higher the ramp the more energy that the ball could have.

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 the students they will generate more variables and analyze them in their groups.

Variables:

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 group notepad. After each prediction, survey the table and write down how many members of the group agree with the prediction and how many disagree. If there is extra time, go around the table a second time. An example of the group notepad can be seen below. Students do not need to record the variables or predictions into their notebooks.

Prepare one student to share a variable and why they think it will affect ball motion during the group discussion.
Wrap-Up:
(3 minutes – Full Class – SciTrek Lead)

Have one student from each group share a variable that they generated and how/why they think it will affect ball motion. Make sure that students tell you their predictions about how different values of that variable will affect ball motion. Challenge students to justify their thinking and explore with them how this might help them design an experiment to answer the class question. For example, if a student’s variable was ball mass and they predicted that the larger the ball mass, the shorter the time for the ball to hit the board, ask the student why they predicted this. One possible answer could be: the largest ball mass will pick up the most speed as it rolls down the ramp. Probe the students deeper by asking them questions such as: if you designed an experiment to test this do you think it would be easier or harder to see if this variable affected the time for the ball to hit the board if you had ball masses that were close together? Students should respond that it would be harder to see the effects of the variable if the ball masses were close together. Therefore, they should choose values that are far apart for their experiment.

Tell the students that the next time we meet they will design an experiment to answer a question that they have about this experiment, which will help them learn about ball motion.

Clean-Up:

Before you leave, collect student nametags and attach them to their notebooks, which are in the group box. Bring all materials back to UCSB. In addition, put your lab coat into your group box.
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:
- ☐ Student nametags
- ☐ Student notebooks
- ☐ Volunteer instructions
- ☐ Volunteer lab coat
- ☐ (5) Materials pages (one for each possible variable)
- ☐ (2) Pencils
- ☐ (2) Wet erase markers

Other Supplies:
- ☐ (4) Large group notepads
- ☐ Board (45cm × 30cm) with outdoor carpet
- ☐ Board (60cm × 30cm) with outdoor carpet

Lead Box:
- ☐ (3) Blank nametags
- ☐ (3) Extra student notebooks
- ☐ Lead instructions
- ☐ Motion picture packet
- ☐ Lead lab coat
- ☐ (5) Materials pages (one for each possible variable)
- ☐ Time card
- ☐ (2) Pencils
- ☐ (2) Wet erase markers
- ☐ (4) Marker (purple, green, blue, orange)
- ☐ Purple ball (27 cm circ., ~360 g)
- ☐ Red ball (27 cm circ., ~55 g)
- ☐ Green ball (30 cm circ., ~200 g)
- ☐ Green ball (21 cm circ., ~200 g)
## Notebook Pages and Notepad Pages:

### SCIENTIFIC PRACTICES

**Testable Questions**

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

<table>
<thead>
<tr>
<th>Question</th>
<th>Testable</th>
<th>Not Testable</th>
<th>Measure</th>
<th>Not defined</th>
<th>Data</th>
<th>Count</th>
<th>Not defined</th>
<th>Not defined</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. How much does an astronaut's suit weigh?</td>
<td>Testable</td>
<td>Not Testable</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Do dogs like Astronaut ice cream?</td>
<td>Testable</td>
<td>Not Testable</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Is Venus prettier than Saturn?</td>
<td>Testable</td>
<td>Not Testable</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. How many moons orbit around Jupiter?</td>
<td>Testable</td>
<td>Not Testable</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Which planet, other than Earth, is the most testable?</td>
<td>Testable</td>
<td>Not Testable</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. How many telescopes are there in the United States?</td>
<td>Testable</td>
<td>Not Testable</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. Is the space shuttle big?</td>
<td>Testable</td>
<td>Not Testable</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9. Is studying the solar system valuable?</td>
<td>Testable</td>
<td>Not Testable</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10. What color light do stars give off?</td>
<td>Testable</td>
<td>Not Testable</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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

### 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 I change the ramp height?**

### NON-SCIENTIFIC QUESTIONS

- Does the ball like rolling down the ramp?
- Will Batman’s car go down the ramp fast?
- Is the ramp big?
- What kind of ball is better, a big one or a small one?
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).

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 I 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.

**EXPERIMENTAL SET-UP**

Determine the values of your changing variable (ex: ball mass) from the materials page and write the values (ex: 15 g) for your 4 trials under each set-up.

<table>
<thead>
<tr>
<th>Trial A</th>
<th>Trial B</th>
<th>Trial C</th>
<th>Trial D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ball mass</td>
<td>~165 g</td>
<td>~165 g</td>
<td>~55 g</td>
</tr>
</tbody>
</table>

Controls (variables you will hold constant):

- Object type: ball
- Ramp length: 50 cm
- Circumference: 27 cm
- Run material: carpet
- Ramp height: 22 cm
- Run length: 200 cm

Predictions:

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

I predict when the ball mass is ~55 g, the ball will hit the board in the least amount of time.
**Set-Up:**

**SciTrek Lead:**
If the classroom has a document camera, ask the teacher to use it for the question activity (page 3, student notebook). If the classroom does not have a document camera, then tape the example poster-size notebook pages to the front board.

**SciTrek Volunteer:**
Set out student notebooks.
- If students are not in the classroom before SciTrek starts, set out the notebooks where students should sit when they come into the classroom.
- If students are in the classroom before SciTrek starts, set out the notebooks where students should sit during the module, they will move to these spots after the introduction.

**Introduction:**
*(2 minutes – Full Class – SciTrek Lead)*

If needed, while you are doing the introduction have the volunteers set out notebooks/nametags where they would like students to sit. Tell students that a notebook will be put on their desk, which is not their notebook and they should not move it.

Ask students what they did during the last meeting with SciTrek. They should reply they did an experiment in which they changed the run material and timed how long it took a ball to roll down two different runs, one made from outdoor carpet and one made from shag carpet. They learned that the outdoor carpet (which was smoother) caused the ball to hit the board in less time than the shag carpet. In addition, they generated other variables that might affect ball motion. Ask the class if they remember the class question they will investigate. They should reply, “What variables affect ball motion?”

Ask the students why scientists might 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 will roll faster on a smooth surface than on a bumpy surface, which suggests that other objects in motion will travel farther and faster on a smooth surface than on a bumpy surface.

Tell students that one way scientists answer questions is by performing experiments; today they are going to generate testable questions about the ramp set-up, after which they will be able to pick a question and design an experiment to answer that question. But first, we are going to look at a list of questions and decide whether each question is testable by science.

If needed, tell students they will now get into their groups.

**Question Activity:**
*(20 minutes – Full Class – SciTrek Lead)*

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

Write on the board:
- **Testable Questions:**
  - Measurable
  - Observable
  - Countable
Ask the 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. Example: 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. Example: Which are prettier, lilies or daisies?
   - Not well defined questions contain words such as affected, react, etc. Example: Do squirrels react to dogs?
   - Not well defined questions can contain semi-measurable words such as big, wide, heavy, etc. Example: 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

Tell the students to turn to page 3 of their notebooks, while you place a blank notebook under the document camera and turn to page 3. Read the directions aloud to the class. Read the first question to students, then give them approximately 15 seconds to circle the answer. Have students share what they think is the correct answer and why. 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 that they will now box the correct answer. Remind them not to erase the original answer because then they will be able to see which concepts/categories they are struggling with. Box the correct answer on the class notebook for students to copy.

If the question is testable, have students tell you what they would measure/count/observe to find the answer to the question. Then, write what they would do next to the question (measure, count, or observe). If the question is not testable, first have the students identify the part of the question that is not testable and why (if applicable underline the non-testable word in the question). Write why the question is not testable next to the question. Second, have the students propose a related question that is testable.
Below are the answers to 1-10 on page 3 in detail.

**Number 1:** How much does an astronaut’s suit weigh?
*Testable (Easy to Test–Measurement)*

Is this question testable?
Yes.

What could be measured/observed to answer this question?
Measure the weight of an astronaut’s suit.

**Number 2:** Do dogs like Astronaut Ice Cream?
*Not Testable (Opinion/Not Well Defined-Contains the Word Like)*

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?

**Number 3:** Is Venus prettier than Saturn?
*Not Testable (Opinion/Not Well Defined-Comparison)*

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?
Number 4: How many moons orbit around Jupiter?

Testable (Easy to Test-Counting)
Is this question testable?
Yes.
What could be measured/observed to answer this question?
Count the number of moons that orbit around Jupiter.

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

Not Testable (Opinion/Not Well Defined)
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?

Number 6: How fast does Luke Skywalker fly his spaceship?

Not Testable (Can’t Acquire Data)
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?

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

Testable (Hard to Test)
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.

Number 8: Is the space shuttle big?

Not Testable (Opinion/Not Well Defined-Semi Measurable)
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?

Number 9: Is studying the solar system valuable?

Not Testable (Opinion/Not Well Defined, Students Think the Answer is Yes)
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. Because students think the answer to the question is yes, they do not think about whether it is testable or not testable.

How can we revise this question to make it testable?

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

**Number 10:** What color light do stars give off?

*Testable (Easy to Test-Observation)*

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 that they are going to generate their own testable questions about the ramp set-up that they used last SciTrek visit. They will be able to use the variables that they generated last time to help them with their questions. Make sure that students understand that 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 ___________________?

Tell students that they can insert a variable into blank 1 and something that they can measure/observe into blank 2 to generate a testable question.

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

Example:

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

Tell the students that they 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 come up with 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. Example: What is the longest ramp in the world? The data that would need to be collected is measure the length 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 notepad can be seen below.
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 if the question is testable and if so what data the group would need to collect to answer the question.

Tell students there are a lot of questions that science cannot answer. Ask the students if they know the types of questions science cannot answer. They should be able to generate the following two categories of questions that science cannot answer:

Category 1: Can’t acquire data
Category 2: Not well defined/opinion

Ask the students if someone can give an example question about the ramp set-up that science cannot answer.

Example Category 1 Question: Does the ball roll down the ramp at the same speed in Neverland?
Example Category 2 Questions: Does the ball like rolling down the ramp? or Is learning about ball motion important?

Tell students that they are now going to generate questions that science cannot answer about the ramp set-up with their group.

Non-Testable Questions:
(4 minutes – Groups – SciTrek Volunteers)

Have the students generate a list of questions that science cannot answer and record them on the group 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 these questions are not testable and have them use these 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 notepad can be seen below.

![Image](image.png)

**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 if the question is testable and if not why.

Tell students that they are going to design an experiment to determine how one variable affects ball motion. First, they will pick their changing variable and record it in their notebooks. Tell students that some options for their changing variable are ramp height, ramp length, ball mass, ball circumference, and run length, while showing students the example materials as they are being discussed. Second, they will discuss why they think this variable will affect ball motion and determine their experimental question. Third, they will use the materials page to determine the values of their changing variable and controls. Fourth, they will determine their experimental set-up. Ask students how 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. Tell students that they need to keep a few things in mind when they are going through this process.

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).
Question:
(4 minutes – Groups – SciTrek Volunteers)

Have students 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. Encourage your group to have a changing variable that is not being explored by other groups. Once they have decided their changing variable, record it on the group notepad and have students record it in their SciTrek notebooks.

As a group, discuss why/how they think their changing variable will affect ball motion. Record their thoughts on the group 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 of the group notepad/student notebook is shown below.

Select one group member to read their question during the wrap-up.

Materials Page:
(5 minutes – Groups – SciTrek Volunteers)

Get the materials page (shown below) that corresponds to the changing variable that your group selected. Have students use the materials page to determine the values for their changing variable and controls. Encourage your group to explain why they are picking the values they are selecting. For instance, when selecting the values of the changing variable, ask students if they think a wide or a narrow range of values would help them more effectively answer their question.

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 this would affect answering their question. This might get them to realize that a 50 cm run would have a very short time, resulting in all 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 their 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 seen below.

---

**Experimental Set-Up:**

*(5 minutes – Groups – SciTrek Volunteers)*

Have students turn to page 5 in their notebooks while you turn to page 7 of the group notepad. Ask your group what they decided was going to be their changing variable and what values of the changing variable they chose for each trial; then record these on the group notepad. After, have students copy the changing variable and its values into their notebooks.
Ask your group what controls and values they selected. Write the control on the left side of the slash and the value of the control on the right side of the slash (example run material / outdoor carpet). In addition, have students copy these into their notebook. An example experimental set-up can be seen 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 extra 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](image)

**Wrap-Up:**
*(3 minutes – Full Class - SciTrek Lead)*

Have one student from each group share the question that they will investigate. Tell students that on the next SciTrek visit they will start their experiment. Tell students that all of their experiments will help us answer the class question: What variables affect ball motion?

**Clean-Up:**

Before you leave, have each student attach their nametag to their notebook and place them in the group box. Place the materials page on the top of the notebooks in your group box. Bring all materials back to UCSB. In addition, put your lab coat into your group box.
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:

- ☐ Student nametags
- ☐ Student notebooks
- ☐ Volunteer instructions
- ☐ Volunteer lab coat
- ☐ (2) Pencils
- ☐ (2) Wet erase markers
- ☐ Notepad
- ☐ Measuring tape (152 cm)
- ☐ Measuring tape (300 cm)
- ☐ Ruler
- ☐ (3) Timers
- ☐ Requested wood ramp holder or lab jack
- ☐ Requested ball(s)
- ☐ Large binder clip

Other Supplies:

- ☐ (4) Large group notepads
- ☐ Requested ramps lengths
- ☐ (4) Ball stop boards 65 cm x 30 cm
- ☐ Box with 4 electronic scales
- ☐ (4) 6 ft x 2 ft outdoor carpet

Lead Box:

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

<table>
<thead>
<tr>
<th>Ball Material</th>
<th>Time Ball Travels (s) (in Increasing Order)</th>
<th>Median (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Styrofoam Ball</td>
<td>6.5, 7.5, 8.5, 9.5</td>
<td>8.0</td>
</tr>
<tr>
<td>Metal Ball</td>
<td>1.5, 1.5, 2.5, 3.5, 2.5</td>
<td>2.5</td>
</tr>
<tr>
<td>Wooden Ball</td>
<td>2.5, 2.5, 3.5, 4.5</td>
<td>3.0</td>
</tr>
<tr>
<td>Plastic Ball</td>
<td>3.5, 4.5, 4.5, 5.5</td>
<td>4.5</td>
</tr>
<tr>
<td>Velcro Ball</td>
<td>2.5, 2.5, 3.5, 3.5, 3.5, 2.5</td>
<td>3.0</td>
</tr>
</tbody>
</table>

### 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, D) 360 g.

4. Roll balls 200 cm and time.

5. Repeat 2 more times.

6. Find median number for each trial.
**Set-Up:**

**SciTrek Lead:**

If the classroom has a document camera, ask the teacher to use it for the technique discussion (page 7, student notebook). If the classroom does not have a document camera, then tape the example poster-size notebook page to the front board.

**SciTrek Volunteer:**

Get materials that 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.

Set out student notebooks.

- If students are not in the classroom before SciTrek starts, set out the notebooks where students should sit when they come into the classroom.
- If students are in the classroom before SciTrek starts, set out the notebooks where students should sit during the module, they will move to these spots after the introduction.

Students will fill out the procedure, results table, and technique section of their notebook while sitting in their groups at the desk/table. During the experiment, students will leave their notebooks at their desks and results will be filled out on the group notepad. After the experiment is completed, students should return to their desks, copy the data into their notebooks, and find the median of the four trials.
**Introduction:**
(3 minutes – Full Class – SciTrek Lead)

If needed, while you are doing the introduction have the volunteers set out notebooks/nametags where they would like students to sit. Tell students that a notebook will be put on their desk, which is not their notebook and they should not move it.

Ask the class, what we have been working on the last two meetings. They should be able to tell you that they have been exploring ball motion and they learned that the smoother the run material the shorter the time it takes for the ball to hit the board. Remind students that last time they picked another variable that they are going to explore today. Ask students if they are going to run 1 or multiple trials. Students should respond multiple trials. Ask students if they have multiple numbers for each trial, what number they will use for their graph. Students should respond the middle number, which is called the median. Tell students that we will practice getting the median from other scientists’ data.

If needed, tell the students to get into their groups.

**Technique:**
(7 minutes – Full Class – SciTrek Lead)

Tell students to turn their notebook to page 6. Place an example notebook under the document camera. Tell students that to find the median, they 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 they 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 of a student notebook page can be found below.

Tell students they will use this technique of finding the median when they perform their experiment.

Tell students that before they can carry out their experiment, they need to write a procedure. Ask the class what a procedure is. They should tell you it is a set of steps to conduct an experiment. Tell them once they have determined their procedure they will fill out their results table and carry out their experiment.
**Procedure:**

*(18 minutes – Groups – SciTrek Volunteers)*

Ask the students to tell you what they picked for their changing variable and what they think they will learn from their experiment.

Tell students they will now generate a procedure for their experiment. Ask students what a procedure is. They should tell you that it is 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 (key control values, changing variable values, and what data they will collect). An example step if ball mass is the changing variable would be, “Get plastic 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 group notepad. As each step is completed, have students copy it from the group 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 procedure can be seen below.
**Results Table:**

*(5 minutes – Groups – SciTrek Volunteers)*

Fill out the variable section of the results table while students fill out the same section in their notebook. When writing the values, make sure that for controls, they only write the value of the control in Trial A and then draw an arrow through the remaining trials; for the changing variable, they write the value in each of the boxes. An example results table can be seen below.
Experiment:

(25 minutes – Groups – SciTrek Volunteers)

Once students have completed the variables section on their results table, have students move to their materials on the floor. Volunteers will fill out all data on the group 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. Record the data that the students collect on a paper notepad (found in your box). Then, have the students tell you how to arrange the numbers from smallest to largest and copy them into the group notepad (see an example below). For each ball roll, have the students select the median from your recorded numbers. This should be done before the ball is rolled again. The median number is the only number the students will record in their notebooks. On the group notepad, each trial will have a total of nine recorded times. The student notebooks will have three numbers recorded for each trial. Remember to record time to the nearest fraction of a second (example 1 2/5 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.

When the 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 group notepad. An example group notepad and student notebook can be seen below.
If there is extra time, have students explain to you what they did 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 that during the next SciTrek visit they will analyze their data by making a graph as well as a poster, which they will use to present their findings to the class. These posters will help us learn about what variables affect ball motion.

Clean-Up:

Before you leave, have each student attach their nametag to their notebook and place them in the group box. Bring all materials back to UCSB. In addition, put your lab coat into your group box.
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:
- □ Student nametags
- □ Student notebooks
- □ Volunteer instructions
- □ Volunteer lab coat
- □ Poster diagram (full page)

Poster Parts:
- □ Scientists’ names
- □ Question
- □ Experimental set-up
- □ Procedure

□ Sticker set for how to present graph (changing ball/changing ramp)
- □ (8) Partial graph pieces
- □ (2) Pencils

□ Results table
- □ Results graph
- □ Results summary

□ (5) Paperclips
- □ (2) Wet erase markers
- □ Highlighter
- □ Scissors
- □ (2) Glues
- □ Scotch tape

(6) “I acted like a scientist when ________”
- □ (6) Picture spaces

Other Supplies:
- □ (4) Large group notepads
- □ Poster paper tube

Lead Box:
- □ (3) Extra student notebooks
- □ Lead instructions
- □ Motion picture packet
- □ Poster diagram (full page)
- □ Lead lab coat
- □ Time card

□ (2) Sticker sets for how to present graph (changing ball/changing ramp)
- □ (8) Partial graph pieces
- □ (2) Pencils
- □ (5) Paperclips

□ (2) Wet erase markers
- □ (2) Highlighters
- □ Scissors
- □ (2) Glues
- □ Scotch tape
- □ Poster part pack (1 each color)
Set-Up:

SciTrek Lead:
Ask the classroom teacher for a place to leave the student posters in the classroom.

SciTrek Volunteer:
Set out student notebooks.
- If students are not in the classroom before SciTrek starts, set out the notebooks where students should sit when they come into the classroom.
- If students are in the classroom before SciTrek starts, set out the notebooks where students should sit during the module, and they will move to these spots after the introduction.

Introduction:
(2 minutes – Full Class – SciTrek Lead)

If needed, while you are doing the introduction have the volunteers set out the notebooks/nametags where they would like students to sit. Tell students that a notebook will be put on their desk which is not their notebook and they should not move it.

Ask the class, “What is the class question that we have been investigating?” Students should reply: “What variables affect ball motion?” Tell students they are going to analyze their results from their experiments which will allow them to start answering the class question. Then they will put together a poster to show their findings to the class. Tell them they should write as neatly as possible on the poster parts so that the other class members can read their poster.
If needed, tell students to get into their groups.

**Graph:**

(10 minutes – Groups – SciTrek Volunteers)

Ask your group what they did the last time. 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 can be used as an example. On the bottom line, have students write the value of their changing variable (example: 150 g), not the trial letter or the changing variable (example: A or ball mass). This way when the pieces are rearranged, they will be able to see the values for each of the trials. 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 showing the median time for their trial as well as write in 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 that 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 group notepad so that they look like a complete graph (see example group notepad below). When taping the graph pieces to the group 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 the students what their changing variable was. Record this answer for the x-axis title and have students copy this into their notebooks.
Results Summary:
(10 minutes – Groups – SciTrek Volunteers)

Have students summarize their findings. Challenge students to think about how their changing variable did or did not affect ball motion.

When writing their results summary, make sure that students start the statement with a claim about the trend or pattern in their data and then write “because” and use data to back up the claim. The data from this experiment is in the form of measurements.

If the values of their changing variable have an order (example: 13 cm → 15 cm → 25 cm) then that variable affected ball motion. If, on the other hand, there was no order for their changing variable (example 150 g → 250 g → 50 g) and the difference between the times is small, then that variable did not affect ball motion. If possible, try to have students generate a claim that allows them to make a prediction about something that 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 the students to make a prediction about what would happen if new values of their changing variable were introduced. After generating a claim about the experiment, write the word “because” and follow it with specific supporting data (the 150 g ball traveled $1 \frac{3}{10}$ seconds and the 250 g ball traveled $1 \frac{3}{10}$ second as well). The supporting data should be the two most convincing data points, typically the minimum and maximum times.

The results summary is still valid, and important, if it shows that the changing variable tested did not affect ball motion. Even if their results summary is contrary to what you think, have students make a claim based solely on their data. Help students copy this statement into their notebooks on page 9.

Before starting their poster, have students fill in the sentence frame (page 10): “I acted like a scientist when_____. “ This should be unique and specific for each of the students and should NOT be “when I did an experiment.” If students are having trouble with this sentence frame, ask them what they did during each SciTrek visit.

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 part.
Use the following guidelines when assigning poster parts:

<table>
<thead>
<tr>
<th>Number of Students in Group</th>
<th>Poster Division</th>
</tr>
</thead>
<tbody>
<tr>
<td>Each student gets an “I acted like a scientist when_____” and picture space.</td>
<td></td>
</tr>
</tbody>
</table>
| 5                           | 1. Question  
2. Experimental Set-Up  
3. Procedure  
4. Results Graph*  
5. Results Summary  
   Student that finishes 1st completes the results table (not presented) |
| 6                           | 1. Question  
2. Experimental Set-Up  
3. Procedure (Presents 1st half of procedure)  
4. Results Table (Presents 2nd half of the procedure)  
5. Results Graph*  
6. Results Summary |
| 7                           | 1. Results Table (Presents names)  
2. Question  
3. Experimental Set-Up  
4. 1st Half of Procedure  
5. 2nd Half of Procedure  
6. Results Graph*  
7. Results Summary  
   Procedure can be cut in half. |

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

Once all writing sections are completed, have students draw a picture of their experiment or how they acted like a scientist.

In the students’ notebooks, highlight and number the section 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 ______” from their poster. If a student is presenting multiple sections, use the paperclips in your group box to clip together the sections that they are reading so that when presenting, it will be easy to flip back and forth between pages.
Place one of the following sentence frame stickers on the top of the notebook page of the student that is presenting the results graph (page 9).

The ball with a _______ of_________ hit the board in _______ seconds.

The ramp with a _______ of_________ hit the board in _______ seconds.

Then practice reading the four sentences with that student. For the poster below, the sentence would be: The ball with mass of 150 g hit the board in \(1\frac{1}{10}\) seconds. Make sure you fill in the first blank (example mass) for the student in the sentence frame but leave the other blanks (“changing variable value” and “measurement”) empty.

As soon as students have completed some of their pieces, start gluing them onto the large poster paper exactly as they are arranged in the example below. 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 that students read from their notebooks instead of off 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 experiments that they did not perform but are related to their experiment.

If there is additional time, tell students that the other students will ask them questions during their poster presentations. Tell them that they should think about what questions they will be asked and then think of the answers to those questions so that they will be prepared during their presentation.
Wrap-Up:
(5 minutes – Full Class – SciTrek Lead)

Ask the students the following questions:
How did you act like a scientist during this project?
What did you do that scientists do?

After having a discussion about how they acted like scientists and talking about how everyone does things that scientists do in their everyday lives, tell students that they will present their findings during the next SciTrek visit and that you are looking forward to hearing about all of their experiments.

Clean-Up:

Before you leave, have each students attach their nametag to their notebook and place them in the group box. Leave student posters in the classroom. Bring all materials back to UCSB. In addition, put your lab coat into your group box.

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:
☐ Student nametags ☐ Volunteer lab coat ☐ (2) Paperclips
☐ Student notebooks ☐ (2) Pencils ☐ Highlighter
☐ Volunteer instructions
Lead Box:

- (3) Extra student notebooks
- Lead instructions
- Motion picture packet
- Lead lab coat
- Time card
- Teacher evaluation
- (2) Sticker sets for how to present graph (changing ball/changing ramp)
- (2) Pencils
- (2) Wet erase markers
- (4) Paperclips
- (2) Highlighters
- Scotch tape

*Student posters should already be in the classroom.

**Picture Packet Page:**

![Image of the picture packet page showing data tables on variables affecting ball motion.]

**Set-Up:**

**SciTrek Lead:**

If the classroom has a document camera, ask the teacher to use it for the notes on presentations (page 2, picture packet). If the classroom does not have a document camera, then write the class question on the board, “What variables affect ball motion?” Leave enough room to record student findings under the question.

Organize the posters so that groups that had the same changing variable present back to back.

**SciTrek Volunteer:**

Set out student notebooks.
- If students are not in the classroom before SciTrek starts, set out the notebooks where students should sit when they come into the classroom.
- If students are in the classroom before SciTrek starts, set out the notebooks where students should sit during the module, they will move to these spots after the introduction.
Introduction:
(2 minutes – Full Class – SciTrek Lead)

Tell students that today they will present their poster to the class. Inform students that 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.

Tell the students that they will have 15 minutes to discuss their experiment/results and practice presenting their poster with their group. While discussing their experiment/results students should not look at their notebooks or poster. Remind students to read from their notebooks when presenting. Tell students that after practicing, they will return to their normal classroom seats.

Practice Posters:
(15 minutes – Groups – SciTrek Volunteers)

Lead Note: Instead of having students explain what they found to their volunteer, you can have the volunteers switch groups and then students can explain and practice their poster with a new volunteer.

If the posters are not already in order, the lead should organize the posters so the experiments featuring the same changing variable are presented back to back.

Once students have gotten to your group, have students explain what they did and what they learned from their experiment. Ask students questions to make sure that they understand what they did during their experiment. Make sure that you also have them use their results to predict what would happen for other systems that they did not test. Remind them to think about patterns or trends that 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 to predict the time that 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 that each student in your group answers one question.

Once your group has an understanding of their experiment, 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 students that the other students will ask them questions during their poster presentations. Tell them that they should think about what questions they will be asked and then think of the answers to those questions so that they will be prepared during their 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 that we have been working on solving?” Students should tell you, “What variables affect ball motion?” Ask the class, “Why are we interested in answering this question?” Students should say that if they can determine the variables that affect ball motion then they will be able to predict other types of motion. Tell students that
during the presentations you are going to take notes. Turn to page 2 in the picture packet. Tell them that they need to tell you each group’s changing variable after the group says their question so that you can record it. You will then record the values of the changing variable when the group presents the experimental set-up, as well as the data that was taken when the group presents their graph.

After each presentation, students will be given the opportunity to ask scientific questions to the presenting group to help them determine if/how the variable investigated affected ball motion. Tell them these questions are important because they will have to summarize for you what they learned from the group so you can record it on the group notes. Therefore, their questions should focus on helping them 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 SciTrek 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?” Each group should answer approximately five questions (one question per student).

Below is an example of notes that the lead could have taken during the poster presentations.

![Notes Example](image)

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.

- Ball mass does not affect the time it takes for the ball to hit the board.
- The longer the run length the more time it takes for the ball to hit the board.
• The taller the ramp (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.
• The 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.
• The ramp length does not affect the time it takes for the ball to hit the board.

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

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

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

Wrap-Up:
(2 minutes – Full Class – SciTrek Lead)

Tell the students that the volunteers that have been working with them are undergraduate and graduate students that volunteer their time so that they can do experiments. Have the students say thank you to the volunteers. This is the last day with their SciTrek volunteers, therefore, they should say goodbye to them. Tell students that you will be back one more time.

Tell students to remove the paper part of their nametag from the plastic holder and that they can keep the paper nametag but they need to give the plastic holder back to their SciTrek volunteer.

Clean-Up:

Before you leave, collect the plastic nametag holders and put them in the group box. Students can keep the paper part of their nametag. Collect notebooks and place them in the group box. Leave student posters in the classroom. Bring all materials back to UCSB. Remove tape from the lid of your group box and place inside. In addition, remove all materials from lab coat pockets, remove your nametag, unroll lab coat sleeves, and put your lab coat into the dirty clothes bag at UCSB.

Day 6: Question Assessment/Tie to Standards/Content Assessment

Schedule:

Question Assessment (SciTrek Lead) – 10 minutes
Tie to Standards (SciTrek Lead) – 40 minutes
Content Assessment (SciTrek Lead) – 10 minutes
Materials:

Lead Box:
- ☐ (3) Extra student notebooks
- ☐ Student notebooks
- ☐ Lead instructions
- ☐ Motion picture packet
- ☐ Lead lab coat
- ☐ (25) Question assessments

☐ (25) Content assessments
- ☐ Time card
- ☐ (2) Pencils
- ☐ (2) Wet erase markers
- ☐ (2) Light blue balls (27 cm circ., ~265 g)
- ☐ Purple ball (27 cm circ., ~360 g)
- ☐ (2) Wood ramp holders (13 cm tall)
- ☐ Wood ramp holder (22 cm tall)

Other Supplies:
- ☐ 5 ft x 2 ft outdoor carpet with measurement mark
- ☐ 125 cm x 30 cm of Astroturf
- ☐ (2) Boards (50 cm x 30 cm) with outdoor carpet
- ☐ Board (50 cm x 30 cm) with Astroturf
- ☐ (2) Boards (50 cm x 30 cm) with marks on back side

Notebook Pages:

TIE TO STANDARDS

1. What two measurements do you need to get the speed of an object?
   - Time and distance

2. If all distances are equal, the ball that hits the board first has a (faster, slower) speed.

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 “Tie” if the two balls tied.

<table>
<thead>
<tr>
<th>Set-Up 1</th>
<th>Set-Up 2</th>
<th>Prediction</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ramp Height: 15 cm</td>
<td>Ramp Height: 20 cm</td>
<td>2</td>
<td>Tie</td>
</tr>
</tbody>
</table>

4. Does the ramp height affect the speed of the ball? YES NO

5. Explain how ramp height affects the speed of the ball.
   - The taller the ramp, the faster the ball hits the board.

Ball Mass

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

<table>
<thead>
<tr>
<th>Set-Up 3</th>
<th>Set-Up 4</th>
<th>Prediction</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ball Mass: 265 g</td>
<td>Ball Mass: 360 g</td>
<td>4</td>
<td>Tie</td>
</tr>
</tbody>
</table>

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

Run Material

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

<table>
<thead>
<tr>
<th>Set-Up 5</th>
<th>Set-Up 6</th>
<th>Prediction</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Run Material: Turf</td>
<td>Run Material: Wood</td>
<td>5</td>
<td>Tie</td>
</tr>
</tbody>
</table>

12. Which set-up will cause the ball to hit the board first? Tie
Set-Up:

SciTrek Lead:

Give the teacher the QR code and ask them to go to the website (at a later time) and fill out the evaluation on the program.

Teachers that are not leading the tie to standards should be filling out an extra notebook along with students.

If the classroom has a document camera, ask the teacher to use it for the tie to standards activity (pages 10-12, student notebook). If the classroom does not have a document camera, then tape example poster-size notebook pages to the front board.

Assemble the tie to standards set-up (seen in picture below as well as on page 3 of the picture packet). Use the following steps to help you with the set-up:

1. Roll out the 5 ft × 2 ft carpet onto the 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).
2. 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).
3. Align the ramps so that the bottom of the ramps are sitting on the 50 cm mark on the carpet.
4. Set the ball stop board at the 150 cm mark (Set-Up 1).
5. 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).

Pass-out notebooks to students. If you do not have time to get set-up before the start of the module, ask the teacher to pass-out the notebooks during the question assessment.
Remind the teacher to give you their lab coat at the end of the day.

**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 the students the following instructions: “On the count of three, I want everyone to stand up and move around the carpet set-up so that you are able to see our experiment. The people in the front must sit so that those behind them can see. I will make sure that everyone is able to see before I start the trials, but remember that 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 the experiment have students return to their seats. Tell students that we will repeat this process two more times during the session.

**SciTrek Volunteer:**

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. For the wooden ramp turn the outdoor carpet ramp 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. One of the ways that we get program funding is by demonstrating the program effectiveness. Therefore, we need you to do your best on the assessment.” Pass-out the question assessment and tell students to fill out their name, teacher’s name, and date on the top of the assessment. Remind the students that it is important that they fill out this assessment on their own.
Read the instructions to the students. Then read each of the questions and tell the students to circle “testable” for questions that science can answer or “not testable” for questions that science cannot answer.

When students are finished, have them turn over their paper. Read the three attitudes towards science questions to students and have them answer them. When they are finished, collect the assessments and verify that the students’ names are on the top of the papers.

Pass-out the draw a scientist paper. Tell students to fill out 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. Then collect the papers from students’ verifying that their names are on the top of the papers.

**Tie to Standards:**
(40 minutes – Full Class – SciTrek Lead)

Tell the class that you enjoyed their poster presentations the last time you were there. Tell the students that today they are going to revisit some of the variables that affected ball motion. Have students turn to page 10 of their notebooks. Place an example notebook under the document camera and turn to page 10.

**Speed vs. Time (5 minutes)**

Ask students what they were measuring during their experiments. Students should reply that they 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 that you heard some of the students talking about ball speeds during the module and you were wondering what they meant by this because it seems like they only measured the time. Therefore, how would they be able to tell anything about speed? By the end of the conversation, make sure that students understand that to get a speed they need time and distance. If students have trouble coming up with time and distance ask them if it is fair to have two students race, one running one lap around the school and the other running ten laps around the school. Ask them which student will finish the race first and why. Students should be able to determine that the student running one lap will finish a lot faster than the student running ten laps, therefore in order to accurately determine speed they need both time and distance. Since both time and distance were measured during the experiment they can talk about the speeds of the balls. Have students fill in questions 1 and 2 on page 10. See example below.

```
TIE TO STANDARDS
1. What two measurements do you need to get the speed of an object?
   time and distance
2. If all distances are equal, the ball that hits the board first has a _______ speed.
   faster
```

**Effects of Ramp Height (10 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 board first. Fill in the result of trial 1 on the example notebook under the document camera. Repeat the process two more times for trials 2 and 3.

Ask the students if the ramp height affects the time the ball takes to hit the board. Students should respond 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 example 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 Table]

Ask students if they 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 a slope of ~45° (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 90° from the run. Ask students if this ball will 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 it takes more time for the ball to hit the ball stop board when the angle is great. 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 lose a significant amount of energy and therefore, the ball does not travel as far. The extreme of this is seen 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 ball 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 example 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 they do not tie, should you hear one hit or two hits when the balls hit the board?” (2 hits) If they tie, you should only hear one hit. Have the students close their eyes and listen to what happens.

Ask the students if ball mass affects the time the ball takes to hit the board. Students should respond 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 example 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 that you will now drop the light blue and purple balls onto the wooden run. Have students predict which ball will hit the wooden run first and 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 your left hand and hold the other ball in your right hand. Make sure that the balls are at approximately 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 to compare and contrast when balls of different masses are rolled down a ramp and when they are dropped. Students should realize the mass does not affect the speed the ball travels in either of the two cases.

**Teacher 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 (10 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 example notebook under the document camera. Repeat the process two more times for trials 2 and 3.

Ask the students if run material affects the time the ball takes to hit the board. Students should respond 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 sentence in the example notebook and have students copy it into their notebook. See example student work below.

![Example Notebook](image)

**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 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 masses of the balls are the same) and the balls all started at the same height, all balls have the same amount of stored energy. Since the balls all have the same amount of stored energy the balls should all have the same final speed. However, experimentally students will see that the balls hit the stop board in slightly different amounts of time. They will find that the smaller the angle between the table top and the ramp (resulting in a less steep slope) the faster the ball will travel (the sooner it will hit the ball stop). 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 the ball 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 ramp. The extreme of this phenomena 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.

![Diagram of angle between ramp and table](image)

**Motion Predictability (5 minutes)**

Ask students if they think ball motion is predictable. Have a few students share their answers with the class. Tell the students that you 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 in more or less time? Students should respond less. When designing this set-up there are only a few variables that you can choose from and you would like their help to identify the variables that you should use. Have students individually go through the variables in question 14(a) and circle each value that 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.

<table>
<thead>
<tr>
<th>Is motion predictable?</th>
</tr>
</thead>
<tbody>
<tr>
<td>14. Circle the values below that would cause a ball to travel at the <strong>fastest speed</strong>. 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.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Variable</th>
<th>Option 1</th>
<th>Option 2</th>
<th>Option 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ramp Height:</td>
<td></td>
<td></td>
<td>Either</td>
</tr>
<tr>
<td>Ball Mass:</td>
<td>100 g</td>
<td>1000 g</td>
<td>Either</td>
</tr>
<tr>
<td>Run Material:</td>
<td>Sand</td>
<td>Plastic</td>
<td>Either</td>
</tr>
</tbody>
</table>

| 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. |

<table>
<thead>
<tr>
<th>Variable</th>
<th>Option 1</th>
<th>Option 2</th>
<th>Option 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ramp Height:</td>
<td></td>
<td></td>
<td>Either</td>
</tr>
<tr>
<td>Ball Mass:</td>
<td>7 g</td>
<td>10 g</td>
<td>Either</td>
</tr>
<tr>
<td>Run Material:</td>
<td>TP</td>
<td>Cardboard</td>
<td>Either</td>
</tr>
</tbody>
</table>
Tell the students that you have enjoyed working with them and you have learned a lot about ball motion from them. You now know that motion is predictable and the ball mass does not affect the speed of the ball but that ramp height, ball circumference, and run material will affect the speed. Tell them before you leave there is one last thing that they need to do.

**Content Assessment:**
(10 minutes – Full Class – SciTrek Lead)

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

Tell the students that they can keep their SciTrek notebooks and that you have enjoyed working and learning with them. You hope they continue to see themselves as scientists and explore the world around them.

**Clean-Up:**

Bring all materials back to UCSB.

**Extra Practice Solutions:**