Big Idea/ Topic

This sample lesson example focuses on the introduction to one-dimensional motion within the Physics GSE.

Standard Alignment

SP1. Obtain, evaluate, and communicate information about the relationship between distance, displacement, speed, velocity, and acceleration as functions of time.

a. Plan and carry out an investigation of one-dimensional motion to calculate average and instantaneous speed and velocity.

- Analyze one-dimensional problems involving changes of direction, using algebraic signs to represent vector direction.
- Apply one-dimensional kinematic equations to situations with no acceleration, and positive, or negative constant acceleration

Connection to other content areas:

ELAGSE11-12RI1: Cite strong and thorough textual evidence to support analysis of what the text says explicitly as well as inferences drawn from the text, including determining where the text leaves matters uncertain.

ELAGSE11-12RI7: Integrate and evaluate multiple sources of information presented indifferent media or formats (e.g., visually, quantitatively) as well as in words in order to address a question or solve a problem.

ELAGSE11-12W1: Write arguments to support claims in an analysis of substantive topics or texts, using valid reasoning and relevant and sufficient evidence.

Instructional Design

Prerequisite student knowledge: Students should be familiar with scalar and vector quantities prior to this lesson and understand that scalar quantities (distance and speed) include magnitude and vector quantities (displacement, velocity, acceleration) include magnitude and direction.

Phenomenon: A flying baseball may break a window or dent a vehicle's body, but the same flying baseball can also be caught harmlessly with a bare hand. Think about the difference. Why might it exist?

Engage:

Synchronous: Show video: Unbelievable Catch. Using a live collaboration tool to show ideas, have students ask questions about what is different about the barehanded catch versus the baseball hitting a parked car. Next, using collaboration spaces, break students into small groups to let them consider the various questions the class developed. There should be various questions and hypotheses relating to motion including speed of the baseball. (If not, the teacher should comment and ask probing questions to get speed into the discussion.)
Writing opportunity: At the completion of collaboration, have students develop a priority hypothesis including reasoning that can be used as an anchor reference during the remainder of the unit.

Asynchronous: Show video: Unbelievable Catch. Using a collaboration space where students can make short posts that can be viewed by other students at a later time (one simple sentence per thought) related to what they believe may be happening. (It is important to limit this so students don't research and write long replies.) In this collaboration space, students may respond to their classmate's posts as well. Writing opportunity: At the completion of collaboration, have students develop a priority hypothesis including reasoning that can be used as an anchor reference during the remainder of the unit.

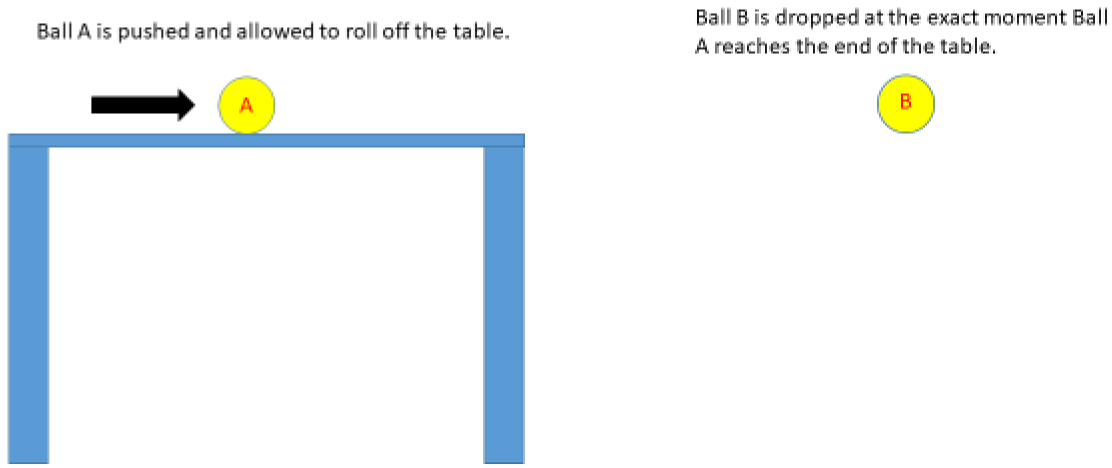
Low/No Technology: Video link above is under 1 minute so students may be able to view it on a phone if available. If completely unplugged--describe the scenario: *Former MLB player Kevin Mitchell is known for an amazing bare-hand catch of a fly ball at the left field fence. Mitchell caught a ball that had traveled approximately 100 meters (328 feet or more than the length of a football field) with his bare hand without injury. The same ball if it had hit a car would have damaged it and if it hit a window, it would have almost certainly shattered it.* Writing opportunity: Students should write a short explanation (one paragraph) explaining why they believe there is a difference between the baseball hitting a car and hitting the player's hand. This written explanation should include their reasoning to bring out prior knowledge as well as any misconceptions.

Explore: Note: *The goal of this explore is to get students to look into motion in two-dimensions. While the part of the standard the overall lesson is looking at is specifically tied to one dimensional motion, students must understand that horizontal and vertical motion are independent of one another. Many teachers operate only in one dimension and then when students master that, they move into two dimensions. The approach taken by this lesson sequence is that many real-world phenomena are two-dimensional, and students should learn that horizontal and vertical motion are independent from the beginning. This approach also allows the teacher to use the same phenomenon throughout the one-dimensional and two-dimensional motion portions of standard SP1.*

Student Exploration: Students should plan and carry out an investigation to observe the independence of vertical and horizontal motion. They will most likely have a misconception about this although some students will have heard about the idea that an object fired horizontally and a stationary object that is dropped hit the ground at the same time. Many students will believe that because an object with initial horizontal motion covers a greater distance when falling that it must take longer. The goal of this exploration is to have students come to the realization of horizontal and vertical independence.

Synchronous: Pose the question, which will hit the ground first, an object fired horizontally, or a stationary object dropped from the same height? Students should have some time to develop their own ideas and reasoning here. Using a live collaboration space, students may share their ideas or share in small groups. The key is to have students share their reasoning. Next, students should consider ideas on how to develop a model to test their theory with something available to them. Ideally, students will come up with creative ways to model the object fired vs. dropped idea, but they may need guidance. If so, using any number of demonstrations (there are many from flipping pennies: Projectile Motion Demonstration the first 40 seconds of this video from Flipping Physics: Projectile Motion Experiment will get students thinking in the right direction.

Example:



Have students manipulate their models making different changes to discover the limitations of their model. (Ideas such as the horizontally fired item must be parallel to the ground will assist them when they move onto projectile motion.)

Asynchronous: Similar to synchronous but use a collaboration space for students to share their ideas on how to build their models. This will allow creativity to be shared and students to provide feedback to one another prior to developing and testing their models.

Low/No Technology: Many of the demonstration videos are short and may be viewed on a phone if available to get the process going. If no technology is available, you may give students a lab-at-home project idea to test the theory with instructions. An example would be a simple home experiment. Have the student, while stationary; throw a ball straight up in the air. It will return to them if thrown vertically. (No surprise to anyone). Now have the student run at a constant speed and tossing the ball straight up into the air. The student will then be able to catch the ball when it returns if their speed is constant. The conclusion the student must make is that even though the ball was thrown vertically (from the running student's frame of reference), it's initial horizontal motion remained the same which is why the student could later catch it while they continued to run. (ignoring air resistance)

Explain:

Synchronous/Asynchronous: Show this test demonstration from Harvard for a test of this experiment:

Challenge students to compare their model to Harvard model and explain any discrepancies.

Low/No Technology: The above video is 1.5 minutes and may be watched on a phone easily, but if that is not an option, the video clearly shows that an object fired horizontally and one dropped from the same exact height take the same amount of time to hit the ground.

Writing opportunity for all students: Explain what you observed with your model including a discussion of the speed and velocity changes that occurred in your model. How does it compare and contrast with the Harvard model? (for synchronous/asynchronous only) What are the limitations of your model? What conclusions can you make about the relationship of vertical and horizontal motion?

Elaborate:

Have students compare this model and observation with other things such as paper airplanes, balled up vs sheet paper, foam balls vs rocks, etc. What are the similarities and differences? (ex: why doesn't this work for a paper airplane? – while this is not part of this standard, you are setting the stage for the forces unit and the concept of air resistance).

Additional option for Synchronous/Asynchronous students: Use the PhET Lab Projectile Motion (Phet Interactive Simulations, University of Colorado at Boulder, https://phet.colorado.edu, licensing for use). Have students click on the VECTORS option and then when the simulation begins, turn on components and vectors on the far right. They may wish to also click on slow for slow motion. Have them predict (by drawing arrows) what the vectors for the projectile will look like in components and then test their predictions.

Angle fired from	Predicted initial vertical vector	Observed initial vertical vector	Predicted vertical vector just before hitting the ground	Observed vertical vector just before hitting the ground	Predicted initial horizontal vector	Observed initial horizontal vector	Predicted horizontal vector just before hitting the ground	Observed horizontal vector just before hitting the ground
60 degrees								
45 degrees								
30 degrees								

This will set the tone for the next section where students will go deeper into standard SP1a.

Evaluate: Have students draw their model for comparing horizontal and vertical motion using vector components at different points in the drawing and explaining how the horizontal motion and vertical motion change throughout the object's travels. This should be a short evaluation as the teacher is just ensuring that the knowledge of the independence of vertical and horizontal motion is in place before moving on.

Next step:

Now that students have a firm understanding that horizontal and vertical motion are independent of one another, we can approach the initial phenomenon of the flying baseball from the viewpoint of SP1a and conduct calculations using average and instantaneous speed and velocity as well as our kinematic equations.

Engage:

Synchronous: Using the same phenomenon, pose the question: How fast was the baseball going when Mitchell caught it? What information do we need to determine this? (students should be thinking about horizontal and vertical speed, time, distance, height, acceleration, etc.) Have students share their ideas in a real-time virtual space and provide feedback to one another.

Asynchronous: Using the same phenomenon, pose the question: How fast was the baseball going when Mitchell caught it? What information do we need to determine this? (students should be thinking about horizontal and vertical speed, time, distance, height, acceleration, etc.) Have students share their ideas in a collaborative space and provide feedback to one another.

Low/No Technology: Pose the question: What information would we need to know to be able to figure out how fast the ball was going when Mitchell caught it in our originally presented phenomenon? (students should be thinking about horizontal and vertical speed, time, distance, height, acceleration, etc.)

For all learners: The teacher should pose questions that get students to understand that they must calculate a horizontal and vertical speed to determine how fast the baseball was going. This is the opportunity to get students thinking about calculating average and instantaneous speed and velocity.

> ***Teacher hint:*** *The intent of the standard is not to derive kinematic equations. While deriving the equations may be useful to the mathematically advanced student, the activities up to this point have primed all students to understand the relationships of the variables needed to apply the kinematics equations which is demanded by the standard.*

Explore and Explain:

The standard says: *Plan and carry out an investigation of one-dimensional motion to calculate average and instantaneous speed and velocity.* This is where they should do that. They should be able to calculate the horizontal speed of our baseball at this point using distance/time and the video. The ball travelled an estimated 100m (based on the left field depth of the ballpark) in about 4.6 s (timed from the video, but "plugged in" students can come up with their own time. Allow students to compare.

Vertical takes more work and an understanding of the kinematic equations. Teachers may wish to provide direct instruction here. Students know from their prior knowledge and the first part of this lesson that some combination of displacement, time, initial velocity, final velocity, and acceleration is needed, but they may often need some assistance in "seeing the relationship". After direct instruction with the kinematics equations, students will be ready to tackle the vertical part of this problem.

Pose the question, if the baseball was in the air for 4.6s, what was the final vertical velocity of the ball? Allow students to work together on determining how to use the kinematics equations to find the answer. Teacher hint: You may have to ask questions about when the vertical velocity is zero to guide students to understand how they can find this.

Synchronous: allow students to work in real-time in groups.

Asynchronous: use collaborative boards for students to work together and provide feedback to one another's work and thinking.

Low/No Technology: Textbooks are helpful here. One free access text is Openstax book can be found here. Sections 2.1, 2.2, 3.1, and 3.2 are helpful. Teacher one-on-one and student collaboration (using district approved methods) may be needed as the pitfalls of learning the kinematics equations are many and direct instruction is often needed to get past points of confusion.

Pose the question: What is needed to choose the correct equation? (Students must be able to articulate that they need to know a certain number of variables as well as which unknown they are looking for to choose the correct equation).

Some helpful websites for kinematics equation instruction in a virtual world:

- Kinematics Part 1: Horizontal motion
- Kinematics Part 2: Vertical motion

Elaborate:

During this elaborate section, student should revisit their model of the object pushed off the table horizontally and the object dropped. Using the kinematics equations, calculate the following:

For the object pushed off the table, measure and/or calculate:

- Horizontal displacement (from the end of the table)
- Vertical displacement
- Final vertical velocity just prior to hitting the ground
- Initial and final horizontal velocity

For the object dropped, measure and/or calculate:

- Vertical displacement
- Final vertical velocity just prior to hitting the ground

This is also where you add a problem set for practice (instantaneous speed/velocity, average speed/velocity, and kinematics problems) using both vertical and horizontal components. There are many problem sets readily available online and through any physics textbook.

Evaluate: While the ability to solve one dimensional problems in the elaborate section will show if students can calculate and use the equations correctly, an authentic assessment would be to require students to find their own individual real-life motion example and prove their knowledge as described in element *a*.

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Next: Students are now ready to move into SP1b (graphing motion) and SP1d (calculating 2-d motion). As a bonus, the horizontal and vertical velocities calculated for the baseball can be used as an intro into 2-d motion. The same phenomena can be used for both of these elements as well.

Evidence of Student Success
• At this point students should have a firm understanding of the independence of horizontal and vertical motion and be able to use the kinematics equations to solve problems. • The assessment item will require students to demonstrate their understanding of the previous concepts. • Problem: Javier is a punter on the North High football team and boasts of his ability to kick a football to a greater height above the ground than any previous player at North High allowing for a long hang time. (Hang time is the time from when a punter kicks the ball to the time the ball is caught by the opposing team or hits the ground. Longer hang times can give a team an advantage by allowing their teammates to get further downfield). • If Javier punts the ball a horizontal distance of 42 m and it is measured to have a hang time of 4.5s, what is the initial horizontal velocity of the football when it leaves Javier's foot? What is the initial vertical velocity of the football when it leaves Javier's foot? If there is a bird flying 30 m above the field, is it possible that the bird may be hit by this football? • Students should be able to calculate these answers using this information.

Distance Learning Supports

The goal for science education in the state of Georgia is as follows: All Students, over multiple years of school, actively engage in science and engineering practices and apply crosscutting concepts to deepen their understanding of the core ideas in these fields.
The learning experiences provided for students should engage them with fundamental questions about the world and with how scientists have investigated and found answers to those questions.
This lesson includes the disciplinary core ideas, science and engineering practices and crosscutting concepts to actively engage students in exploring science concepts with real world topics. As part of the vision we must support the inclusion of all students in science learning.

Some **general** ideas to consider when planning lesson supports are as follows:

- Be sure that students can access the information that you they are learning. Make sure that you can answer the following questions:
    - Do students have what they need to get the information? This is about them having the book or internet access to get to the information.
    - Once students obtain the information, are students able to determine what information is important? This is about the students having materials on the appropriate grade level and that is in a format that students can understand.
    - Is the material presented in multiple ways that allows all students to interact with information in a way that works for them? Such as video, audio, and articles.
    - Consider read aloud as a potential option for students that have reading deficits as an option to assist students in accessing the material. This could be done using video or via phone.
- Students may need ideas about where to find information. Providing students with information about what a reliable source is and even where to find reliable sources may be beneficial for students.
- Some students may find it difficult to complete the entire lesson workload. Some students may benefit from a reduced workload (note: this should be used only when absolutely necessary). Be sure that the information that is removed will not negatively impact the student's understanding of the disciplinary core idea.
- Consider how students show their knowledge. Students need multiple ways and opportunities to show their knowledge. Things to consider:
    - Recording video or audio
    - Drawing
    - Writing
    - Typed
    - Verbal
- Provide students with a way to ask questions in a forum that does not cause anxiety. Frequently students do not want to ask questions in front of their peers because they are afraid of what their peers may think of them. So, be sure to provide students a way to ask questions that is private or anonymous.
- Consider materials that students need to complete the assignments.
    - Do students have needed materials?
    - What are some alternative materials that students may have available to them?
- Have a clear and consistent set of guidelines for providing consistent feedback to all students.
- Utilize graphic organizers such as those from the Wonderofscience.com
- Use high leverage and evidence-based practices to reach all students.

Some ideas to consider for supporting students, **specific to this lesson**, are as follows:

- The teacher should make sure that they communicate to students how to turn on/off the closed caption feature for videos that are shared for student use.
- The teacher should have clear and consistent guidelines for students working together to explore motion. All students should feel that their input is valued and that their work is respected in a shared space.
- The teacher should consider guiding questions to activate prior knowledge and help students make connections to new material.
- The teacher may need to consider sentence frames for writing assignments. This may help students get started writing and more clearly share their knowledge.
- The teacher should provide multiple formats for student to access information. This could include articles, videos, textbooks, and/or direct instruction.
- The teacher should provide students with multiple formats to share their knowledge. These formats could include drawing, writing or verbally explaining.
- The teacher can consider providing students with a rubric to make expectations clear about what is required in the model.
- Consider providing students with a list of common household items that they could use in their investigation. This could alleviate some anxiety and wasted time on trying to identify all parts of the investigation needed.
- The teacher should have clear and consistent expectations for all students. The teacher should make sure that the students understand the expectations for work, collaboration and classroom space etiquette.
- The teacher should consider giving students an example of what the data and vectors should look like while working on the PhET simulation. This should make it easier for students to have needed information when they are done with the simulation.
- The teacher may need to consider some form of read aloud for relevant articles or texts that are needed to complete the assignment.
- The teacher should be sure to give students timely, relevant, clear and positive feedback on their models. This will allow students to improve their models as they work through the lesson.

Engaging Families

- Connect to Georgia Home Classroom resources and the GPB Digital Series for high school physics, Physics in Motion