The Yolks on You!

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Target Grade: 8th grade Mathematics/Physical Science

Time Required: five, 40 minute sessions (200 minutes total)

Standards:

- CCSS.MATH.CONTENT.8.F.B.4 Use functions to model relationships between quantities.
  - Construct a function to model a linear relationship between two quantities. Determine the rate of change and initial value of the function from a description of a relationship or from two (x, y) values, including reading these from a table or from a graph. Interpret the rate of change and initial value of a linear function in terms of the situation it models, and in terms of its graph or a table of values.
- CCSS.MATH.CONTENT.8.EE.C.7.B Analyze and solve linear equations and pairs of simultaneous linear equations.
  - Solve linear equations with rational number coefficients, including equations whose solutions require expanding expressions using the distributive property and collecting like terms.
- CCSS.MATH.CONTENT.8.EE.A.2 Expressions and Equations Work with radicals and integer exponents.
  - Use square root and cube root symbols to represent solutions to equations of the form $x2=p$and $x3=$, where p is a positive rational number.

Note: Although designed for the mathematics classroom, this lesson supports NGSS Standard 3-PS2-2.

Lesson Objectives:

Students will:

- Collect data to build a model of an object moving which produces a linear distance vs. time graph
- Collect data to build a model of an object moving which produces a quadratic distance vs. time graph
- Use and revise their model to predict the time required for an object to move a certain distance

Central Focus:

Students will be tasked with utilizing mathematics and modeling to predict when to release a raw egg from the top floor of the stairwell so that it can strike the head of the instructor walking on the bottom floor. Experiments will be carried out to build a mathematical model of an object falling toward the ground as well as an object walking at a constant pace. Students will extend their model to predict the time required for an object to fall a distance previously not measured and utilize that time to predict the distance the teacher walking below would move. This lesson serves to teach students the power of collecting data to build a model to predict future data points while utilizing mathematics as the means to accomplishing the goal of the problem.

Background Information:

Students

This lesson is designed to directly follow the introduction to solving quadratic equations. Students should be familiar with collecting and graphing linear data as well as solving linear equations. Students are not expected to be familiar with the terms "constant velocity," "constant acceleration," "free-fall," or "gravity" to be successful for the activity, but knowledge of these concepts can be successfully build-upon in the physical science classroom following the activity.

Teacher Background

- Flipping Physics Website
- YouTube Video discussion of constant speed vs. constant acceleration which gives the background information to understand a teacher walking (constant speed) and an egg falling (constant acceleration)
- Discussion of Independence Video Discussion of the independence between mass and acceleration for an object in free-fall
- Teacher should be familiar with google sheets and/or excel on a basic level

Materials

- Claim-Evidence-Reasoning Worksheet (Day 1)
- Teacher Walking Data Worksheet (Day 2)
- Ball Drop Worksheet (Day 3)
- Making Predictions Based Off a Model Worksheet (Day 4)
- De-Briefing Worksheet (Day 5)
- Google Sheets Spreadsheet (Day 4) Google Sheet
- Student device/tablet with access to internet
- Bullet fired/dropped demonstration apparatus (Day 1)

  - See Demonstrator for an example apparatus as well as instruction guide for performing the demonstration
- Video optional myth busters video in place of the demonstration for engaging phenomenon
- Option 2 second optional video in place of the physical demonstration for engaging phenomenon
- Class set of stopwatches (Days 2 and Day 3)
- Smartphone with strobe photo app such as “Motion Shot”
- Measuring tape which is capable of measuring height of tallest drop (feet or meters acceptable) for Days 2 and Day 3
- Tennis ball
- Raw eggs for final experiment (Day 5)
- Protective Helmet for teacher safety (Day 5)
- Poncho or cheap raincoat for teacher safety (Day 5)
- Tablecloths from dollar store, cleaning solution, paper towels to clean up potential mess from eggs (Day 5)
- Optional: Metronome app for teacher phone

Instruction

Day 1

Engage (20 minutes)

- Teacher will present the objectives.
- Students will use and revise their model to predict the time required for an object to move a certain distance.
- Teacher will pass out Claim-Evidence-Reasoning worksheet for engaging phenomenon, state the demonstration, and students will write down predictions.
- Teacher will perform demonstration as directions state from Arborsci datasheet.
- Students will write down observations, make a claim concerning their observation, and providence evidence for their claim based upon their observations.

Explore/Explain (15 minutes)

- Students will read the article in pairs found at http://www.math.wichita.edu/history/men/galileo.html and complete the compare/contrast questions in the worksheet.
- Students will fill out the reasoning section of the worksheet based upon evidence from observations as well as evidence gained from the reading.

Conclude (5 minutes)

- As the students just should have finished up the introduction to solving a basic linear and quadratic equation in the previous unit, the teacher can pause to ask students to examine the paths that each ball takes and compare it to types of lines we have already discussed. The teacher can add that now instead of simply solving an equation, we will be creating and using equations to make predictions.
- Teacher will state essential question to guide instruction for the next four days. "How can a mathematical model be used to compare different sets of data and predict an unknown measurement?"
- Teacher will state the problem students will attempt to solve: "You will be tasked with completing a series of experiments to create a model to predict when to release a raw egg from the top floor so that it is able to hit me on the head as I walk on the bottom floor below."
- Teacher will show a short clip to engage students over the next four days as well as provide context for the problem, https://www.youtube.com/watch?v=cgJ1JYSWwKc\

Day 2

Engage (5 minutes)

- Break students up into groups of three. Try to organize students by learning style (if known) so that each group is composed of a primarily auditory learner, visual learner, and kinesthetic learner. Each student will be able to bring something unique to the table to contribute to the lab.
- Hand out Day 2 worksheet and timers and state the objective of the day:
  - Collect data to build a model of an object moving which produces a linear distance vs. time graph

Explore (20 minutes)

- Students will each record the time it takes for the teacher to walk a set distance. Use of a metronome timer application on your phone set to your own personal gait is extremely helpful to help walk at a constant pace and ensure accurate results.
- Between each set of data, circulate around to check student calculations of average time and look for any outlying data.
- Direct students to enter data into google sheet and print off.

Explain/Elaborate (15 minutes)

- Direct groups to complete questions 1-4 on the worksheet. When complete, go to an open area and walk out the 35 feet.
- Discuss that the number they found on the graph is the rate of change of the function for distance vs. time. Through the Socratic Method, discuss that this is a measure of the teacher's walking speed.

- Questions to elicit thought include:
  - What would the graph look like if I walked faster slower? How do you know?
  - What does it mean to change my distance?
  - What is a rate of change?
- When finished, direct students to complete last question.

Conclude (5 minutes)

- Allow any students with outlying data to alter their model and/or modify their results to ensure that everyone has a working model to use to move on to the next day.
- Discuss ways that data collection could have been improved.

<u>Day 3</u>

Engage (5 minutes)

- Form the same groups as yesterday.
- Hand out Day 3 worksheet and timers and state the objective of the day:
  - Collect data to build a model of an object moving which produces a quadratic distance vs. time graph.

Explore (20 minutes)

- Students will each record the time it takes for the ball to fall a set distance. For this experiment, it may be necessary to alter the spreadsheet to ensure you have available vertical distances for the ball to fall. The rest of the spreadsheet will remain unchanged.
- Between each set of data, circulate around to check student calculations of average time and look for any outlying data. Use of the Key to compare with ideal times will be useful here to help identify large sources of error.
- Direct students to enter data into google sheet and print off.

Explain/Elaborate (15 minutes)

- Direct groups to complete questions 1-5 on the worksheet. When complete, go to tall area of known height and drop the ball.
- When finished, direct students to complete last question.

Conclude (5 minutes)

- Allow any students with outlying data to alter their model and/or modify their results to ensure that everyone has a working model to use to move on to the next day.

* Discuss ways that data collection could have been improved.

Day 4

Before the lesson, it is necessary to know the vertical height of the egg drop. It is also necessary to place a tape marking on the floor showing the straight line distance to the ground. This can be done by hanging a small weight from a long string and marking the location where it hits the ground.

Engage (5 minutes)

- Form the same groups as yesterday.
- Hand out Day 4 worksheet and timers and state the objective of the day:
  - Use and revise their model to predict the time required for an object to move a certain distance
- Present the problem to students once again that they will now use their models to predict when to release an egg from a known distance so that it hits the teacher walking below.

Explore (30 minutes)

- Students will spend class working through the worksheet and attempting to figure out how to time dropping the egg.
- The questions guide students to first consider the time it takes the egg to fall to the ground and how the height of the teacher changes the time.
- Then consider the distance the teacher would walk in that amount of time.
- Then consider how to accurately drop the egg when the teacher is a certain distance away. The best technique is to start the teacher far away and have her walk. Students place a tape mark on the ground where the time for the teacher to move that distance equals the time for the egg to fall to the ground (connection to engaging phenomenon on day 1). Students release the egg when the teacher walks over the tape mark.
- Then students will consider how to ensure that the drop is accurate by dropping the egg straight or constructing a simple device to release the egg.

Conclude (10 minutes)

- As groups finish, direct them to place their marks (with painter's tape) on the floor below showing where the teacher is walking when they will release the egg.
- Students can design a device to release the egg (paper towel roll works well with medium eggs) to release the egg if desired or time allows.

Day 5

Before the lesson, it is necessary to place the tarps/plastic tablecloths on the ground to cover the floor. In addition, the eggs can be pun-afied using a sharpie to write puns on the eggs like Egg-straordinary, Eggs-calibur, Humpty-Dumpty, You Crack me up!, Egg-cellent, and I'm so egg-cited!

Engage (5 minutes)

- Form the same groups as previous.
- Give 2 minutes to allow groups to prepare for the drop and decide on a person to drop the egg
- Discuss clean up procedures following the activity as well as expected behavior by groups during the activity.

Explore (20 minutes)

- Students will take turns dropping the eggs from their marks.
- It is advisable to give each student a practice run where they pretend to drop an egg (with nothing in their hand) while the teacher walks below to get a sense of timing.
- Groups take turns attempting to hit the teacher on the head (make sure to wear helmet and poncho!) with their egg.

Conclude (15 minutes)

- After all groups finish, clean up the area.
- Students are directed to complete the 3-2-1 worksheet to conclude the activity.
- Discuss how the week's experiment would be similar/different if the egg were thrown instead of dropped. This is a lead-in to the next unit, solving problems using the quadratic equation.

Differentiation

This lesson is accessible using the link Google doc. With this, using File-->Language, you can translate the entire document seamlessly if necessary to address needs of ELL students. During Day 1, ELL students can be provided with a shortened and/or highlighted reading activity. Students are grouped by learning style but can also be group by mixed learning levels at the teacher's discretion. If data for the dropped ball is far from ideal, average each group's data to form a class average to use for the calculations on Day 4. For gifted students or as an extension, do not use the premade sheets template and have the students calculate and program the spreadsheet themselves as well as make the graphs. If this lesson is to be taught in the physical science classroom, this lesson should be concluded with an assignment on day 5 for students to write an abstract of the lesson. In addition, this lesson should be used as the lead in to the discussion of distance, velocity, acceleration, and gravity since it builds a strong student conceptual model of the terms. Some students may be completely successful with the work throughout the week, but may miss the teacher due to timing issues or aiming. Be sure to attempt to identify timing and aim issues with calculation issues (which can be determined from the day 4 worksheet).

Assessment

Formative:

- Assessment throughout the lessons. Teacher will evaluate with questions to determine if students are achieving the learning objectives each day.
- Results from claim-evidence-reasoning worksheet to drive instruction for lesson.
- Results from worksheets from Days 2 and 3. Students are able to create a model and accurately predict a previously unmeasured time to move a set distance.
- Predictions from day 4 worksheet

Summative:

- Egg Drop Results. Students who are capable of producing a model to predict an unknown value will be able to accurately hit the teacher with an egg, with the exception of timing issues.
- 3-2-1 worksheet. Teacher will evaluate if students were successful of lesson objectives based upon answers to reflection questions. Results of assessment (especially the question) are used to drive instruction for the next topic. See attached rubric for scoring.

The Yolks on You! -Day 1

Name: _______________________

Date: ____________

Period: __________

Prediction: Which ball will hit the ground first?

Observations: Write down at least four separate observations about the experiment below.

Claim: Based only on your observations (no opinions!) make a claim about what you observed.

Evidence: Provide at least two pieces of evidence (based from observations) to support your claim.

Research: Go to http://www.math.wichita.edu/history/men/galileo.html and read the short story of Galileo. Name at least three things the swinging chandelier and the rolling balls have in common with the demonstration performed as well as one thing you personally found interesting about the life of Galileo.

Reasoning: Based upon your evidence and research, try to provide a reason for what you observed.

The Yolks on You! -Day 1 KEY

Name: ______________________

Date: ____________

Period: __________

Prediction: Which ball will hit the ground first?

Student Opinion

Observations: Write down at least four separate observations about the experiment below.

See both balls hit the ground at the same time

Hear only one "click" sound as they hit

One ball falls straight down

One ball flies forward

Student opinion

Claim: Based only on your observations (no opinions!) make a claim about what you observed.

Both balls hit the ground at the same time

Evidence: Provide at least two pieces of evidence (based from observations) to support your claim.

Sound of balls hitting, sight of balls hitting

Research: Go to http://www.math.wichita.edu/history/men/galileo.html and read the short story of Galileo. Name at least two things the swinging chandelier and the rolling balls have in common with the demonstration performed as well as one thing you personally found interesting about the life of Galileo.

Swings took the same time no matter the arc

Balls fell at the same time no matter the weight43e

Student opinion

Reasoning: Based upon your evidence and research, try to provide a reason for what you observed.

Student opinion, but something leading towards the idea that whatever makes all the objects fall to the ground makes them fall at the same time no matter what.

The Yolks on You! -Day 2

Name: ________________________

Date: _____________

Period: ___________

Partners: _____________________________

Objective: Conduct an experiment to graph the motion of your teacher walking and predict how far she would walk in a certain amount of time.

Experiment: For each distance, you and two partners will collect time for your teacher to walk. In the table below, fill out your data. When complete, find the average time for your group.

Distance	Your Time	Partner Time #1	Partner Time #2	Average Time
1.0				
2.0				
3.0				
4.0				
5.0				
6.0				
7.0				
8.0				
9.0				
10.0				

Graph: Using the excel spreadsheet, fill out your data with the average times. Print out a graph for each member of the team. Write down the equation for your teacher below.

1. If the y-axis is distance and the x-axis is time, re-write the equation in terms of those words.

2. What does the number in the equation mean?
3. How long would it take the teacher to move 5.5 feet? Solve this problem first using the graph, then solve it again using the equation.

4. If you were asked to predict how long it would take the teacher to walk 35 feet, would it be easier to use the graph or the equation? Why?

5. Using your chosen method, predict how long it would take the teacher to walk 35 feet. Write your prediction below and the measured result. Show your work!

   Prediction=

   Measured time=

5. Did your model do a good job of predicting the motion of your teacher? If not, what steps could you take to revise and improve your model

The Yolks on You! -Day 2 KEY

Name: ______________________

Date: ___________

Period: _________

Partners: ___________________________

Objective: Conduct an experiment to graph the motion of your teacher walking and predict how far she would walk in a certain amount of time.

Experiment: For each distance, you and two partners will collect time for your teacher to walk. In the table below, fill out your data. When complete, find the average time for your group.

Distance	Your Time	Partner Time #1	Partner Time #2	Average Time
1.0				
2.0				
3.0				
4.0				
5.0				
6.0				
7.0				
8.0				
9.0				
10.0				

Graph: Using the excel spreadsheet, fill out your data with the average times. Print out a graph for each member of the team. Write down the equation for your teacher below.

Formatting has been done on graph for time purposes. Equation is given on the top right corner.

1. If the y-axis is distance and the x-axis is time, re-write the equation in terms of those words.

Distance = slope (number) x average time

2. What does the number in the equation mean?

Number is the slope. It says how much you walk each second.

3. How long would it take the teacher to move 5.5 feet? Solve this problem first using the graph, then solve it again using the equation.

Graph: trace upwards from t=5.5s

Equation: insert t=5.5 into distance=slope x time to solve for distance

4. If you were asked to predict how long it would take the teacher to move 35 feet, would it be easier to use the graph or the equation? Why?

Equation because it would go far beyond the paper to extend the graph that far

5. Using your chosen method, predict how long it would take your teacher to walk 35 feet. Write your prediction below and the measured result

Prediction=

Measured time=

6. Did your model do a good job of predicting the motion of your teacher? If not, what steps could you take to revise and improve your model?

For students that were off, direct them to revise their model by including additional data points from other students as well as from the 35- foot time to improve their models.

The Yolks on You! -Day 3

Name: ________________________

Date: ____________

Period: __________

Partners: ____________________________

Objective: Conduct an experiment to graph the motion of a dropped ball and predict how long it would take the ball to drop an unknown distance.

Experiment: For each distance, you and two partners will collect time for the dropped ball. In the table below, fill out your data. When complete, find the average time for your group.

Distance	Your Time	Partner Time #1	Partner Time #2	Average Time
1.0				
2.0				
3.0				
4.0				
5.0				
6.0				
7.0				
8.0				
9.0				
10.0				

Graph: Using the excel spreadsheet, fill out your data with the average times. Print out a graph for each member of the team. Write down the equation for the ball below.

1. Compare/contrast today's graph with yesterday's graph.

2. If the y-axis is distance and the x-axis is time, re-write the equation in terms of those words.

3. How long would it take the ball to drop 5.5 feet? Solve this problem first using the graph, then solve it again using the equation.

4. If you were asked to predict how long it would take the ball to fall 35 feet, would it be easier to use the graph or the equation? Why?

5. Using your chosen method, predict how long it would take the ball to fall 35 feet. Write your prediction below and the measured result. Show your work!

   Prediction=

   Measured time=

6. Did your model do a good job of predicting the motion of the ball? If not, what steps could you take to revise and improve your model?

The Yolks on You! -Day 3 KEY

Name: _______________________

Date: ____________

Period: __________

Partners: ____________________________

Objective: Conduct an experiment to graph the motion of the ball falling and predict how far the ball would fall in a certain amount of time.

Experiment: For each distance, you and two partners will collect time for the falling ball. In the table below, fill out your data. When complete, find the average time for your group.

Distance	Your Time	Partner Time #1	Partner Time #2	Average Time
1.0				
2.0				
3.0				
4.0				
5.0				
6.0				
7.0				
8.0				
9.0				
10.0				

Graph: Using the excel spreadsheet, fill out your data with the average times. Print out a graph for each member of the team. Write down the equation for your teacher below.

Formatting has been done on graph for time purposes. Equation is given on the top right corner.

1. Compare/contrast today's graph with yesterday's graph.

This graph is quadratic. Ball takes less time to travel a certain distance. Yesterday's graph was a straight line, this one is curved.

2. If the y-axis is distance and the x-axis is time, re-write the equation in terms of those words.

Distance = number x time^2

3. How long would it take the ball to drop 5.5 feet? Solve this problem first using the graph, then solve it again using the equation.

Graph: Read off the graph same as day two

Equation: Solve for time. Since distance= number x time^2, students can solve for time using algebra. The equation becomes:

$$\text{Time} = \sqrt{\frac{\text{Distance}}{\text{Number}}}$$

4. If you were asked to predict how long it would take the ball to fall 35 feet, would it be easier to use the graph or the equation? Why?

Equation because it would go far beyond the paper to extend the graph that far

5. Using your chosen method, predict how long it would take the ball to fall 35 feet. Write your prediction below and the measured result

   Prediction=

   Measured time=

6. Did your model do a good job of predicting the motion of the ball? If not, what steps could you take to revise and improve your model?

For students that were off, direct them to revise their model by including additional data points from other students as well as from the 35-foot time to improve their model.

See Key in spreadsheet for ideal times to help get an idea where students might be making a mistake. Note: Ignore first and second terms that trend line gives as they will be very small. Key 1 is for measurements in feet and Key 2 is for measurements in meters. Feel free to change the distances as they fit the needs of your class.

The Yolks on You! -Day 4

Name: ________________________

Date: ____________

Period: __________

Partners: _____________________________

Objective: Using the created models, determine when to release the egg from the top floor so that it can strike the teacher on the head.

Height of Drop=____________-

[1] If you drop the egg from the top floor and want to hit your teacher on the head, how does your teacher's height affect the results?

[2] Using your model, predict the time it would take the egg to fall the desired distance.

[3] Using your model, predict how far the teacher would walk in the time found in [2].

[4] Here's the big question. With both of your models, how will you time your drop to hit the teacher on the head? Make sure to list all necessary materials and your procedure. Draw a diagram of the set-up and label all measurements necessary.

[5] What steps will you take to ensure you are as accurate as possible? Remember to consider what is on the line, so accuracy counts

The Yolks on You! -Day 4 KEY

Name: ______________________

Date: ___________

Period: _________

Partners: ___________________________

Objective: Using the created models, determine when to release the egg from the top floor so that it can strike the teacher on the head.

Height of Drop=_dependent on class

[1] If you drop the egg from the top floor and want to hit your teacher on the head, how does your teacher's height affect the results?

Distance of fall = Height-Teacher height.

It will lessen the time

[2] Using your model, predict the time it would take the egg to fall the desired distance.

Using equation distance of fall = number x time^2, students will solve for time. Below demonstrates an example with a height of 45 feet and teacher height of 6.0 feet

$39 = 16t^2$ ------> 39/16=2.4375=t^2-----------> $t = \sqrt{2.4375}$ =1.56 seconds

[3] Using your model, predict how far the teacher would walk in the time found in [2].

Use equation from Day 2, distance = speed x time to solve for distance. Below is a sample calculation for a teacher who walks at a speed of 3.5 feet/second.

Distance = (3.5) (1.56s) = 5.46 feet.

[4] Here's the big question. With both of your models, how will you time your drop to hit the teacher on the head? Make sure to list all necessary materials and your procedure. Draw a diagram of the set-up and label all measurements necessary.

Place a mark 5.46 feet away from where egg will land if dropped. When teacher passes over mark, drop the egg. Use bright tape to make sure mark is easy to see from high up.

[5] What steps will you take to ensure you are as accurate as possible? Remember to consider what is on the line, so accuracy counts!

Any push or pull will make the egg land somewhere other than where it is predicted to land. Use of a small tube to make sure the egg drops straight down is very effective. Practicing the timing of the drop is also useful to anticipate the drop.

The Yolks on You! -Day 5 Debriefing Worksheet

Name: ________________________

Date: _____________

Period: ___________

Partners: ______________________________

Directions: On your own, please complete the following questions. As you answer the questions, consult the attached rubric

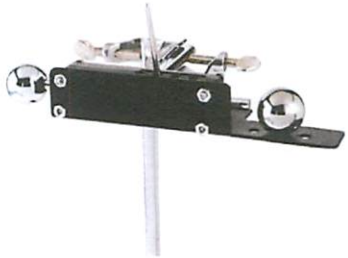
Write down <u>3</u> things that you learned about mathematical models.

Write down <u>2</u> new places where you could use the models you made to make new predictions

Write down <u>1</u> question you still have

Grading Rubric for 3-2-1 Assessment

	Needs Work (+1)	Proficient (+2)	Egg-cellent (+3)
Three Things Learned	Less than three things learned. Statements are repetitive. Student does not demonstrate understanding of learning objectives through work.	At least three unique statements mentioned which demonstrate that student has learned all three learning objectives.	At least three unique statements mentioned which demonstrate that student has mastered all three learning objectives. Statements show depth of thought.
Two Places	Less than two places provided. Repetitive statements. Created models would not be able to be used in situations discussed.	At least two unique statements are given. The created models would be able to supply predictions for the statements given.	At least two unique statements are given. The created models would be able to supply predictions for the statements given. Statements show creativity and depth of thought.
One Question	No question written or question is simply a surface-level question which can be easily answered by “yes” or “no.”	At least one question provided which would require additional experimentation/research to answer.	At least one creative question provided which connects to the topics discussed and would require additional experimentation/research to be carried out to understand.



Vertical Acceleration Demonstrator

P3-3520

KIT CONTENTS:

Launcher apparatus
Two steel balls

ALSO REQUIRED:

Ring stand and right-angle clamp (or other support).

ACCESSORIES/REPLACEMENT PARTS:

Spare balls, pair (P3-3521).
Bullseye Level (P6-2604).
Right Angle Clamp (66-8290)
Ring Stand, 20" (66-4220).

INSTRUCTIONS:

1. Mount the apparatus at least 1.5m above the floor, so that both balls will land on the floor. Use a level to make sure the launched ball will be launched horizontally.
2. Pull the spring and latch the lever in one of the notches. The different spring settings will send the projected ball out at different speeds.
3. Place one ball on the platform, as close as possible to the spring plunger.

4. Place the other ball on the post. Rather than push it all the way in, let it balance near the end of the post.

5. Ask students to predict which ball will land first.

6. Release the spring as rapidly as possible and listen for the balls hitting the floor. Do you hear one simultaneous "click" or two distinct and separate "clicks"?

7. Repeat the demonstration, asking students to close their eyes and just listen.

WHAT'S GOING ON?

First, think about why objects fall. They fall because gravity forces them down. Gravity only acts straight down, and will only affect downward motion. Since the two balls are released from the same height and fall the same distance, the cover that distance in the same time. The fact that one of them is also moving horizontally makes no difference in its travel time.

RELATED PRODUCTS:

Air Powered Projectile (P4-2200). Use equations to accurately predict the motion of this "rocket." It can go up to 100 meters!

Marble Projectile Ramp (P2-8490). Designed to work with a photogate so students can measure the velocity of a horizontal projectile and predict its range.

Galileo Galilei

1564 - 1642

Galileo was born in 1564, the year of Michelangelo's death and Shakespeare's birth. Because of this fact, some say that Galileo was destined to do great things. Galileo's father, Vincenzio Galilei was a musical theorist, who supported his family by selling cloth. Galileo's father, wanting him to prosper more so than himself, strongly encouraged him to attend the University of Pisa to study medicine.

While studying at the university, bored of medicine, he discovered something that fascinated him. Walking through the halls, he glanced in at a class so entranced with the lecturer that he was impelled to listen and watch. As he listened to the geometry lesson, Galileo realized what he really wanted to study. He kept studying medicine at the persistence of his father, but while still in his first year, convinced his father to allow him to study math with a private tutor. Eventually, he quit studying medicine to focus his interests in math. In his time, the study of math, astronomy and science were very closely related. These studies led him to many profound discoveries.

In 1582, while praying in a chapel, Galileo observed a lamplighter lighting the chandeliers. The lamplighter would pull the lamps nearer him with a rod, and after lighting them, let them swing until they hung in place. Timing the swings against his own heartbeat, Galileo discovered the law of pendulum. No matter how wide an arc the lamps made, the time it took to complete a cycle, swinging from one side to the other was the same, even as the size of the arc decreased.

In 1589, at age 25, Galileo was given the position of lecturer in math at the University and was selected as the Chair of Mathematics. During this time, he began to study the works of Aristotle. Challenging some of the ideas of the great scientist, Galileo began to experiment on his own. Many of his colleagues thought him mad and ignored his studies. Wanting to disprove Aristotle's theory of falling objects, Galileo devised an experiment. In order to gain the respect of his colleagues, he heavily advertised the upcoming experiment. With the aid of two of his students, Galileo took two metal balls, one of which weighed ten times as much as the other. Dropping them from the top of the Leaning Tower of Pisa, his students timed each of the balls' falls. When Galileo's theory was proven correct, that no matter the weight, the balls would fall at the same rate and land at the same time, his colleagues still did not believe him, accusing him of using magic to alter the falls.

A better position was available, and in 1592, he left Pisa and became professor of mathematics at the University of Padau near Venice. There, he remained until 1600 when, at age 45, he was asked by Grand Duke of Tuscany, Cosmo II to be the Chief Mathematician in his court in Florence.

In 1609, Galileo revised the spyglass to create a telescope, improving magnification from 9 times to 32. With this new creation, Galileo began his study of the ever-mysterious heavens. He discovered many things with his telescope, such as mountains on the moon, and moons around Jupiter. In 1610, Galileo's first scientific book *The Starry Messenger* was published, describing what he had seen. With his new findings, Galileo also began to compare the theories of Ptolemy (which stated that all planets, including the sun orbited the Earth) and Copernicus (which stated that the sun was the center of the universe). Galileo's findings supported Copernicus' theory, which was against the beliefs of the church. In 1616, Galileo was called to the Roman Inquisition and made to promise to no longer publish or defend the Copernican theory.

After two more calls to the Roman Inquisition, Galileo was convicted of heresy and incarcerated. Shortly after his incarceration, his sentence was lessened to house arrest. For the last 8 years of his life, Galileo lived in his estate at Arcetri. Still studying mathematics, and with the aid of several faithful students, he wrote more on his studies of motion. Forbidden to publish, at least one known book(*Discourses on Two New Sciences*) was smuggled from the country to be published elsewhere. In 1642, at age 78, having led a full life of discovery, Galileo died, apparently of natural causes.

Contributed by Lindsay Eastridge

References:

1. http://galileoandeinstein.physics.virginia.edu/lectures/gal_life.htm
2. Calinger, Ronald (1995), Classics of Mathematics.
3. Kline, Morris (1990), Mathematical Thought from Ancient to Modern Times.
4. Reimer & Reimer (1992), Historical Connections in Mathematics

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Average Time	Distance (meters or feet)
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	2.00
	3.00
	4.00
	5.00
	6.00
	7.00
	8.00
	9.00
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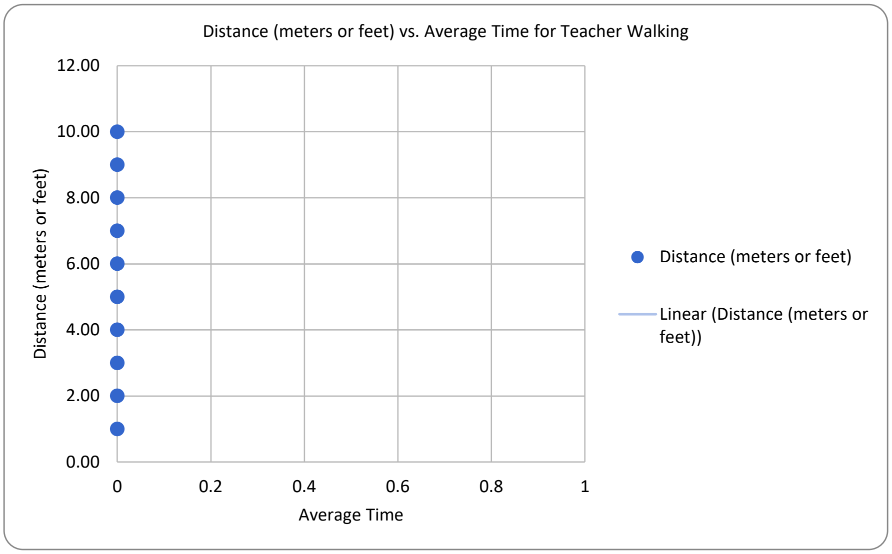

Average Time	Distance (meters or feet)
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	2.00
	3.00
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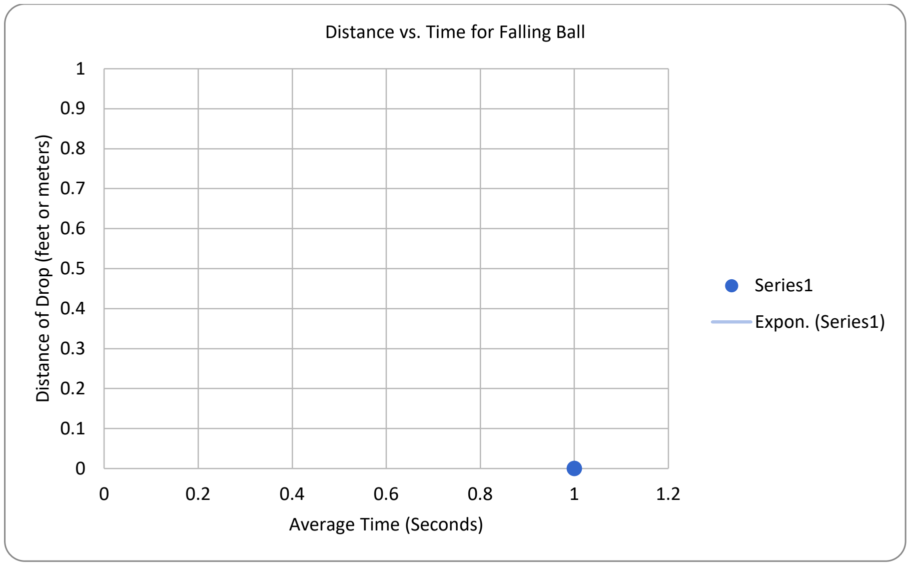

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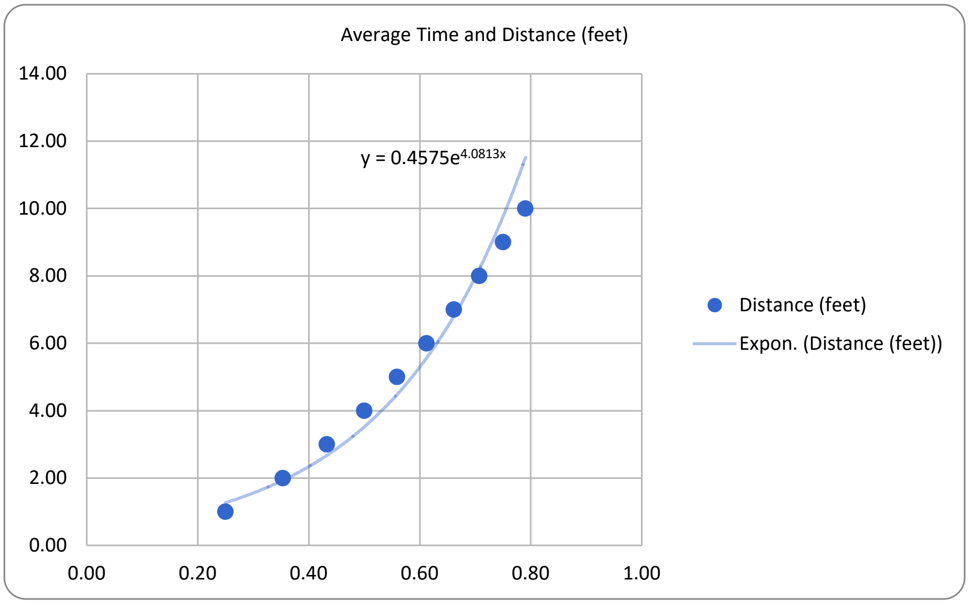
0.79	10.00



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1.19	7.00
1.28	8.00
1.35	9.00
1.43	10.00