STEMapalooza 2018
"Capitalizing the M in STEM"

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Lesson Title: Timed Ball Drop – Math Patterns in Free Fall

Grade Level: 4th

Science:
S4P3. Obtain, evaluate, and communicate information about the relationship between balanced and unbalanced forces.

a. Plan and carry out an investigation on the effects of balanced and unbalanced forces on an object and communicate the results.
b. Construct an argument to support the claim that gravitational force affects the motion of an object.
c. Ask questions to identify and explain the uses of simple machines (lever, pulley, wedge, inclined plane, wheel and axle, and screw) and how forces are changed when simple machines are used to complete tasks.

Math:
MGSE.4.OA.4
Find all factor pairs for a whole number in the range 1–100. Recognize that a whole number is a multiple of each of its factors. Determine whether a given whole number in the range 1–100 is a multiple of a given one-digit number. Determine whether a given whole number in the range 1–100 is prime or composite.

MGSE.4.OA.5
Generate a number or shape pattern that follows a given rule. Identify apparent features of the pattern that were not explicit in the rule itself. Explain informally why the pattern will continue to develop in this way.

MGSE4.NF.6
Use decimal notation for fractions with denominators 10 or 100.

Lesson Essential Question:

- How can I use number patterns to understand the speed and acceleration at which an object falls due to gravity?
- How can I use a simple machine to elevate and then drop a foam golf ball?

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- How can I use the number of seconds a ball is in free-fall to determine the height it fell from?

Vocabulary:
Force
Gravity
Free-fall
Speed
Acceleration
"g" as the "constant" of acceleration due to gravity

Lesson Materials:
Paper tubes
Newspaper
Tape
String
Plastic cups
Simple pulleys
Timers/stop watches
Foam golf balls
Calculators
(Various other materials to build with such as pipe cleaners and straws, craft sticks, etc.)
Optional: pulleys

Lesson Assessment:
Number Pattern in Free Fall Sheet
Student STEM Journal
Team Member Evaluation
Teacher Observation

STEM Challenge Overview:
Students will create a structure taller than they are and then engineer a device that uses a simple machine to raise a foam golf ball to the top of the structure and drop it. They will analyze data from a general free-fall situation, find a pattern, determine and write the rule of the pattern, and then use that rule to determine the height of their structure given the time it takes a golf ball to fall from the top. *Assume no air resistance.

Pre-requiste:
Write a number as a product of its prime factors

Instruction:

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1. Experiment/Investigate, Day 1 (45 - 60 minutes)

Hold a soft foam golf ball in one hand. Ask students what forces are acting on the ball. Point out, or help them discover through questions, that the pull force of gravity on the ball is as strong as the push force of my hand on the ball, though in opposite directions. This makes them balanced forces. If I move my hand, the pull force of gravity is unbalanced and this makes the ball move. Explain that gravity is the force that is making the golf ball move, and will continue to make the golf ball move until it meets an equal and opposite force, such as the floor. Question whether gravity continues to pull on the golf ball after it hits the floor, and even after it has stopped bouncing. If gravity continues to pull on the ball, why does it stop moving? Balanced forces are exerted on it.

Explain to students the following table which shows the total distance an object in free-fall will travel in the given time (*assuming no air resistance). This data comes directly from Newton's motion equations, and displays patterns the students will explore and investigate.

Total distance	Time in seconds
0 meters	0 seconds
5 meters	1 second
20 meters	2 seconds
45 meters	3 seconds
80 meters	4 seconds
??? meters	5 seconds

Ask the students to find the prime factors of each of the total distances. Then ask students to determine the missing number, or distance. Ask the class to write down the number when they think they know it and then raise their hand. Go around and check each students' number and let them know if they are correct or incorrect. If incorrect, encourage them to try again.

Factors	Total distance	Time in seconds
0	0	0
1, 5	5	1
1, 2, 2, 5,	20	2
1, 3, 3, 5	45	3
1, 4, 4, 5	80	4
(1, 5, 5, 5)	(125)	5

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Invite the class to write in their STEM journal the method they used to find the missing number.

Tell the class that there is another way to find the next number and ask them if they can figure it out. If needed, give them a hint to find the missing addend, or the difference between terms to find the pattern in the distance numbers.

Missing Addend	Total Distance	Time in seconds
0	0	0
0 + 5 = 5	5	1
5 + 15 = 20	20	2
20 + 25 = 45	45	3
45 + 35 = 80	80	4
80 + 45 = 125	125	5

Instruct students to write in their STEM journal the pattern they found in the missing addends and how they found the total distance the ball falls in 5 seconds. Invite them to find the total distance the ball will fall for 6 seconds.

Return to the data and connect it back to the real world problem. Ask students what the missing addend means about how far the ball falls. Confirm that the missing addend is the distance the ball falls in just that one given second.

Students will construct and record in their STEM journal an explanation for the effect of gravity on the speed of an object in free fall.

2. Speed and Acceleration, Day 1 (30 minutes)

Discuss the pattern in the speeds. If the ball speeds up from 0 m/s to 5 m/s to 15 m/s to 25 m/s to 35 m/s, what pattern do they see? How fast is it speeding up? It is speeding up 10 meters per second for every second that it falls. Acknowledge that it is speeding up 10 m/s for every second that it falls. How quickly something is speeding up is called its acceleration.

Identify the relationship between the numbers measuring time (seconds) and the numbers measuring distance (meters). Help students notice that the height is equal to five times the number of seconds times the number of seconds again. Extrapolate the rule: distance = 5 x number of seconds x number of seconds. (This is from Galileo's equation: $H = \frac{1}{2} g t^2$ with H being the height or distance fallen, g being 9.8 m/s/s and t being the number of seconds in free fall.)

Define g = 10 m/s/s (explain the actual acceleration is 9.8 m/s/s but we've rounded to 10 m/s/s) as the acceleration of any object in free fall due to gravity (assume no air resistance).

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2. Imagine/Brainstorm, Day 2

Instruct the students that they will be working in teams of 2 or 3. Explain that scientists often work together and rarely get to work with their best friend. Sometimes they even have to work with someone they don't like or know, and that they don't have to become best friends but they do need to speak with respect and kindness. Inform them that they will have a chance to evaluate each other at the conclusion of the project based on the following criteria.

a. Was respectful of your ideas _____
b. Presented their own ideas _____
c. Was willing to compromise _____
d. Communicated clearly and kindly _____
e. Took turns in building and testing the project _____
f. Improved their social interactions when asked _____

Recognize that all students are able to interact socially at different levels. Please encourage the students to answer the questions based on the performance of their partner to the best of THEIR PARTNER'S abilities, rather than compared to their own or another person's abilities.

Instruction to the students: We want to test the rule we found yesterday. Please design a structure that can move a foam golf ball as high as possible, and a mechanism to then drop the golf ball from the top. This will be called the "launcher" though it must drop the golf ball straight down, not launch it with any horizontal thrust.

(*NOTE: This can be done as an add-on to a tower structure that the students have already built, or as an addition to an egg-drop activity, or you can skip the structure building and engineer a device to raise and drop a golf ball from a tree, or a book case, or ladder.)

3. Plan/Design

Draw 2 plans for your launching device that will use a simple machine to raise and then drop a golf ball. Work with a partner to choose 1 of your 4 total plans. Then together draw the plan for the structure with the chosen device attached.

4. Create/Test

Work in teams of 2 or 3 to create the structure and "launching" device. Remember that the ball needs to drop straight down, all the way to the floor, with no horizontal thrust.

Test the device and time the golf ball as it falls. Record the number of seconds the golf ball falls in decimal form and in expanded form using the correct terms for each place value.

5. Analyze/Evaluate/Improve

Plug your data (number of seconds in free fall) into the pattern rule to determine the height of your structure (or the height from which the ball fell). Analyze your data, and compare your results to the actual height/distance. Determine possible causes of discrepancies. Determine if

you can improve the “launch” mechanism of your device to improve the accuracy of your measurements. Can you increase the height or stability of your structure?

Complete the worksheet by evaluating your partner.

Optional:

Discuss the balanced and unbalanced forces when dropping a soft foam golf ball. Explain that gravity is the force that is making the golf ball move, and will continue to make the golf ball move until it meets an equal and opposite force, such as the floor. Question whether gravity continues to pull on the golf ball after it hits the floor, and even after it has stopped bouncing. If gravity continues to pull on the ball, why does it stop moving? Balanced forces are exerted on it.

Conduct an experiment to compare the speed of two objects in free-fall. The objects will have the same size and shape but different weight (mass), such as a solid golf ball and a foam golf ball. Time each as they fall and then compare the times.

Discuss human error. Repeat the experiment several times and notice the difference in the times recorded for how long it takes the ball to drop. Discuss how human error can be minimized.

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