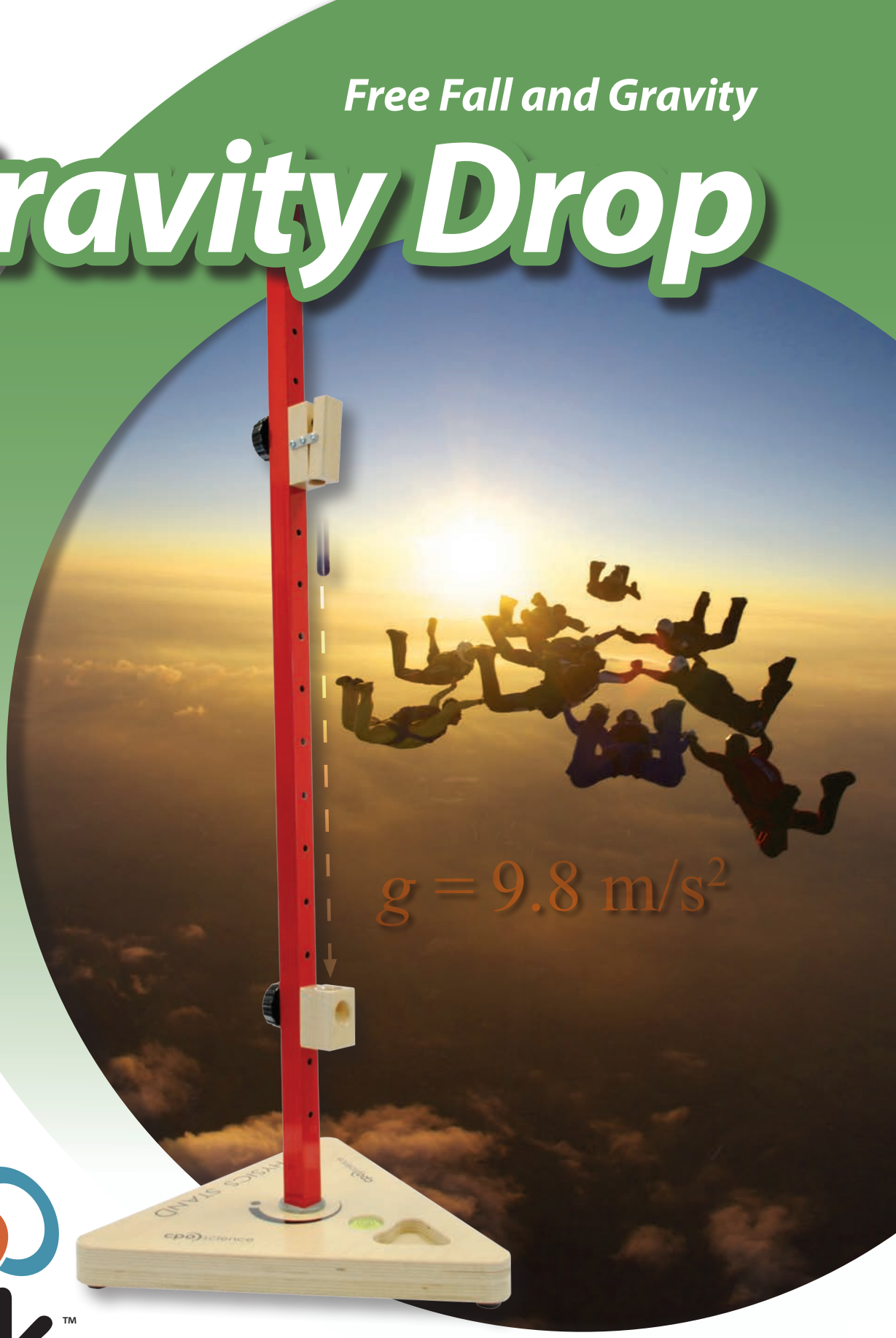
Free Fall and Gravity

Gravity Drop



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CPO Science

Real Investigations in
Science and Engineering

Overview Chart for Investigations–Gravity Drop

	Investigation	Key Question	Summary	Learning Goals	Vocabulary
A1	**Introduction to the Gravity Drop** Pages 1–6 50 minutes	How do you use the Gravity Drop?	Students will use the Gravity Drop equipment to control the path of a falling marble.	• Assemble the Gravity Drop equipment. • Use a plumb line to align the dropper with the catcher. • Release a marble from the dropper with a consistent trajectory. • Practice consistent techniques that lead to good experimental data.	plumb line
A2	**Measuring Speed with the Gravity Drop** Pages 7–12 50 minutes	How do you measure the motion of a falling object?	Students learn to measure the speed of the marble as it falls. The investigation also provides students with an opportunity to develop their understanding of gravity and how it affects falling objects.	• Learn how to measure the time interval of a marble falling through the photogate. • Learn how to calculate the speed of a marble in free fall. • Develop an understanding of gravity.	free fall gravity speed
A3	**Falling Motion** Pages 13–20 100 minutes	How does the speed of a falling marble change?	Students apply their knowledge to examine the speed of the marble at several points along its path. Using this information, they determine how the speed of the falling marble changes over time.	• Make a graph of the motion of a falling marble. • Learn to interpret motion graphs. • Learn the difference between speed and acceleration.	acceleration experiment hypothesis speed
B1	**Free-Fall Motion** Pages 21–28 50 minutes	How do you measure the motion of a falling object?	Students will learn how to set up and use the Gravity Drop and measure the speed of a falling marble.	• Use the timer and photogate to measure the speed of a falling marble. • Use a plumb line to align the dropper with the catcher. • Release a marble from the dropper with a consistent technique.	free fall gravity instantaneous speed plumb line speed
B2	**Speed, Acceleration, and Free Fall** Pages 29–38 100 minutes	How does gravity affect the motion of a falling object?	Students apply their knowledge to examine the speed of the marble at several points along its path. With this information, they determine how the speed of the falling marble changes over time.	• Make a graph of the motion of a falling marble. • Interpret motion graphs. • Explain the difference between speed and acceleration.	acceleration experiment free fall hypothesis percent error slope speed trend line
B3	**Free Fall and Mass** Pages 39–46 50 minutes	Do heavier objects accelerate faster?	Students explore how the weight of an object affects its acceleration. In the process, they will explore Newton's second law.	• Derive an equation to find the acceleration of a marble in free fall. • Compare the average accelerations of the plastic and steel marbles. • Analyze the difference between measured values of acceleration and an accepted value of g using percent error.	force Newton's second law weight

Overview Chart for Investigations–Gravity Drop

	Investigation	Key Question	Summary	Learning Goals	Vocabulary
B4	**Gravity and Impact** Pages 47–52 100 minutes	What is the best way to minimize forces during an impact?	Students use the engineering cycle to design a device that can protect an egg in impact with the ground. Students apply Newton's laws to understand the action of forces during impacts and collisions.	• Become familiar with the engineering cycle. • Create, test, and refine a device to protect an egg in a collision.	constraints criteria engineering cycle Newton's third law prototype trade-off
C1	**Free Fall: Speed vs. Time** Pages 53–62 100 minutes	What happens to the speed of an object in free fall?	In the investigation, students learn to measure the speed of the falling marble and determine how it changes as it falls. Students then learn to graph their results, find slope values, and create a mathematical model to confirm their measurements.	• Graph the motion of a marble in free fall. • Determine the acceleration of the marble. • Develop a model to predict the speed of a falling marble.	acceleration experiment free fall hypothesis percent error slope speed trend line
C2	**A Model for Accelerated Motion** Pages 63–70 50 minutes	What can be learned from graphs of accelerated motion?	Students explore how the area under the trend line in their graphs can be used to determine the displacement of the marble over a given amount of time.	• Use geometry to calculate area of rectangles and triangles. • Calculate displacement from the area on a speed vs. time graph. • Derive an equation for the displacement of a marble.	area displacement
C3	**Free Fall and Acceleration Due to Gravity** Pages 71–80 50 minutes	How do you measure the acceleration of a falling object?	Students apply an equation for the displacement of a falling marble in order to determine acceleration and initial velocity.	• Use an equation for displacement to determine acceleration and initial velocity. • Estimate the acceleration of a falling marble using an iterative mathematical model.	iteration iterative
C4	**Gravity Acting on Different Masses** Pages 81–88 50 minutes	Do heavier objects accelerate more?	Students explore the accelerations of the steel and plastic marbles as they experience free fall.	• Derive an equation to find the marble's acceleration with two photogates. • Collect data and find the average acceleration of the plastic and steel marbles. • Determine if objects of different masses accelerate the same or differently.	force Newton's second law weight

Next Generation Science Standards Correlation

CPO Science *Link* investigations are designed for successful implementation of the Next Generation Science Standards. The following chart shows the NGSS Performance Expectations and dimensions that align to the investigations in this title.

NGSS Performance Expectations	Gravity Drop Investigations
MS-PS2-4. Construct and present arguments using evidence to support the claim that gravitational interactions are attractive and depend on the masses of interacting objects.	A1, A2, A3
HS-PS2-3. Apply scientific and engineering ideas to design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision.	B4
HS-PS2-4. Use mathematical representations of Newton's Law of Gravitation and Coulomb's Law to describe and predict the gravitational and electrostatic forces between objects.	B1, B2, B3, C1, C2, C3, C4

NGSS Science and Engineering Practices	Gravity Drop Investigations
Engaging in Argument from Evidence	A1, A2, A3
Using Mathematics and Computational Thinking	B1, B2, B3, C1, C2, C3, C4
Constructing Explanations and Designing Solutions	B4

NGSS Disciplinary Core Ideas	Gravity Drop Investigations
PS2.B: Types of Interactions	A1, A2, A3, B1, B2, B3, C1, C2, C3, C4
PS2.A: Forces and Motion	B4
ETS1.A: Defining and Delimiting an Engineering Problem	B4
ETS1.C: Optimizing the Design Solution	B4

NGSS Crosscutting Concepts	Gravity Drop Investigations
Systems and System Models	A1, A2, A3
Patterns	B1, B2, B3, C1, C2, C3, C4
Cause and Effect	B4

Common Core State Standards Correlation

CCSS-Mathematics		Gravity Drop Investigations
MP.2	Reason abstractly and quantitatively.	A1, A2, A3, A4, B1, B2, B3, C1, C2, C3, C4
MP.4	Model with mathematics.	A1, A2, B1, B3, C1, C2, C3, C4
6.RP.A.1	Understand the concept of a ratio and use ratio language to describe a ratio relationship between two quantities.	A1, A2
6.RP.A.3	Use ratio and rate reasoning to solve real-world and mathematical problems.	A1
6.NS.C.5	Understand that positive and negative numbers are used together to describe quantities having opposite directions or values; use positive and negative numbers to represent quantities in real-world contexts, explaining the meaning of 0 in each situation.	A3, A4
6.EE.A.2	Write, read, and evaluate expressions in which letters stand for numbers.	A3, A4
7.RP.A.2	Recognize and represent proportional relationships between quantities.	A1, A2
7.EE.B.3	Solve multi-step real-life and mathematical problems posed with positive and negative rational numbers in any form, using tools strategically. Apply properties Apply properties of operations to calculate with numbers in any form; convert between forms as appropriate; and assess the reasonableness of answers using mental computation and estimation strategies	A3, A4
7.EE.B.4	Use variables to represent quantities in a real-world or mathematical problem, and construct simple equations and inequalities to solve problems by reasoning about the quantities.	A3, A4
8.F.A.3	Interpret the equation $y = mx + b$ as defining a linear function, whose graph is a straight line; give examples of functions that are not linear.	A1, A2
HSN-Q.A.1	Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays.	B3, C1, C2, C3, C4
HSN-Q.A.2	Define appropriate quantities for the purpose of descriptive modeling.	B3, C1, C2, C3, C4
HSN-Q.A.3	Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.	B3, C1, C2, C3, C4
HSA-SSE.A.1	Interpret expressions that represent a quantity in terms of its context.	B1, B2, C2
HSA-SSE.B.3	Choose and produce an equivalent form of an expression to reveal and explain properties of the quantity represented by the expression.	B1, B2, C2
HSA-CED.A.1	Create equations and inequalities in one variable and use them to solve problems.	B3, C2, C3, C4
HSA-CED.A.2	Create equations in two or more variables to represent relationships between quantities; graph equations on coordinate axes with labels and scales.	B3, C2, C3, C4
HSA.CED.A.4	Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations.	B1, B3, B2, C2, C3, C4
HSF-IF.C.7	Graph functions expressed symbolically and show key features of the graph, by in hand in simple cases and using technology for more complicated cases.	C2
HSS-IS.A.1	Represent data with plots on the real number line (dot plots, histograms, and box plots).	C2

Common Core State Standards Correlation (cont'd)

CCSS-English Language Arts & Literacy		Gravity Drop Investigations
SL.8.5	Integrate multimedia and visual displays into presentations to clarify information, strengthen claims and evidence, and add interest.	A1, A2
SL.11-12.5	Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest.	C1
RST.6-8.1	Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions	A3, A4
RST.6-8.3	Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks.	A3, A4
RST.11-12.1	Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account.	C2
RST.11-12.7	Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem.	B1, B2, B4, C2
WHST.6-8.7	Conduct short research projects to answer a question (including a self-generated question), drawing on several sources and generating additional related, focused questions that allow for multiple avenues of exploration.	A3, A4
WHST.9-12.9	Draw evidence from informational texts to support analysis, reflection, and research.	C2