Projectile Motion

# Marble Launcher


link™
CPO Science

Real Investigations in
Science and Engineering

# Overview Chart for Investigations–Marble Launcher

| | Investigation | Key Question | Summary | Learning Goals | Vocabulary |
|---|---|---|---|---|---|
| **A1** | **Launch Angle and Distance**<br>Pages 1–8<br>50 minutes | Which launch angle makes the marble travel farthest? | Students will determine the launch angle that causes the marble to travel the greatest distance from the marble launcher. By using the Marble Launcher to make multiple launches while controlling launch angle and speed, they discover that there is more than one angle at which the marble may be launched to reach a given distance. | • Determine the optimum angle for maximum range using graphical analysis.<br>• Prepare a graph to be used for determining launch distance for a prescribed angle. | control variable<br>experimental variable<br>launch angle<br>range |
| **A2** | **Launch Speed and Distance**<br>Pages 9–14<br>50 minutes | How does launch speed affect the distance traveled by the marble? | Students examine the function of the Marble Launcher to identify the relationship between launch speed and the distance which the marble travels away from the launcher. Students launch a marble at a constant angle and different launch speed settings. Students use a graph to analyze their data. | • Measure the distance traveled by a marble at various launch speed settings.<br>• Graph distance vs. launch speed setting.<br>• Identify the graphical relationship between distance traveled and launch speed. | launch speed |
| **A3** | **Playing a Reliability Game**<br>Pages 15–22<br>50 minutes | How reliable is the Marble Launcher? | Students measure the reliability of the Marble Launcher by determining the probability of the marble reaching a given landing area. Students use their findings play a game. | • Describe the reliability of a device.<br>• Investigate probability.<br>• Change the forces acting on an object, and describe the object's motion using probability. | probability<br>reliability |
| **B1** | **Launch Angle and Range**<br>Pages 23–28<br>50 minutes | Which launch angle will give a marble the greatest range? | Students find the launch angle for achieving maximum range with a projectile. Students discover that multiple launch angles will yield the same range and use graphs to analyze and display their data. The topic of error in measurement is introduced. | • Determine the optimum angle for achieving the maximum range of the Marble Launcher.<br>• Use graphical analysis to determine the range at a specified angle for the Marble Launcher.<br>• Evaluate the data error. | launch angle<br>launch speed<br>projectile<br>range<br>trajectory |
| **B2** | **Launch Speed and Range**<br>Pages 29–34<br>50 minutes | How does launch speed affect the range of a projectile? | Students identify the relationship between launch speed and range. After using the Marble Launcher to gather launch data at different spring settings, students graph range vs. launch speed and discover that the graph is not a straight line, but a curve. | • Measure the range of a marble at various speeds.<br>• Measure the launch speed of the marble.<br>• Graph range versus launch speed. | launch angle<br>launch speed<br>range |

# Overview Chart for Investigations–Marble Launcher

| | Investigation | Key Question | Summary | Learning Goals | Vocabulary |
|---|---|---|---|---|---|
| **B3** | **Relating Launch Speed and Range**<br>Pages 35–42<br>50 minutes | What function relates the range and launch speed of a projectile? | Students analyze data from Investigation B2 in order to determine a function that will show the way projectile range is related to launch speed. | • Prepare graphs relating range and launch speed using different functions of launch speed.<br>• Determine the relationship between range and launch speed using the results of the graphs. | function |
| **B4** | **Engineering Design and Projectile Motion**<br>Pages 43–48<br>150 minutes | How can we control the lateral movement of a launched marble? | Students use the engineering cycle to design a process or solution to limit the lateral motion of a marble launched from the Marble Launcher. During this investigation students have the opportunity to test their prototype, identify and complete modifications, and communicate their results. | • Apply the engineering cycle.<br>• Describe constraints, criteria, and trade-offs.<br>• Design a solution to a real-world problem. | constraints<br>criteria<br>engineer<br>engineering cycle<br>trade-offs |
| **C1** | **Projectile Motion and the Range Equation**<br>Pages 49–58<br>100 minutes | How can you predict the range of a launched marble? | Students use algebra and trigonometry to derive an equation that allows them to predict the range of the marble given the initial velocity and launch angle. They apply the equation to predict ranges and then test their predictions. They compare their set of predicted ranges to a set of ranges gathered experimentally with the Marble Launcher. | • Derive the range equation.<br>• Test a range prediction with actual measurements.<br>• Compare predictions to measurements. | projectile motion<br>range<br>trajectory |
| **C2** | **Improving the Range Equation**<br>Pages 59–66<br>50 minutes | How can you improve the range equation? | Students identify aspects of the marble trajectories that are not taken into account by the range equation derived in Investigation C1. Students revise the equation and develop a new set of predicted range values. Students compare this new set of ranges to the data gathered in C1. | • Correct inconsistencies in the range equation.<br>• Test an equation to predict range, and compare predictions to experimental data. | quadratic equations |
| **C3** | **Accuracy, Precision, and Error**<br>Pages 67–72<br>50 minutes | How repeatable are experiments with the Marble Launcher? | Students determine the accuracy and precision of the Marble Launcher experiments. Using a plot of a set of landing sites on a coordinate plane, students determine the average distance deviation of the sites to one another. From this information, students describe the accuracy and precision of the landings. | • Determine the accuracy and precision of the Marble Launcher.<br>• Create a "spot plot" of marble landings.<br>• Improve predictions of where the marble will land. | accuracy<br>deviation<br>precision |

# 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 | Marble Launcher Investigations |
|---|---|
| MS-ETS1-4. Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved. | A3, B4 |
| MS-PS2-2. Plan an investigation to provide evidence that the change in an object's motion depends on the sum of the forces on the object and the mass of the object. | A1, A2 |
| HS-PS2-1. Analyze data to support the claim that Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration. | B1, C1, C2, C3 |
| HS-PS2-2. Use mathematical representations to support the claim that the total momentum of a system of objects is conserved when there is no net force on the system. | B2, B3 |

| NGSS Science and Engineering Practices | Marble Launcher Investigations |
|---|---|
| Analyzing and Interpreting Data | C1, C2, C3 |
| Developing and Using Models | A3, B4 |
| Planning and Carrying Out Investigations | A1, A2 |
| Using Mathematics and Computational Thinking | B1, B2, B3 |

| NGSS Disciplinary Core Ideas | Marble Launcher Investigations |
|---|---|
| ETS1.B: Developing Possible Solutions | A3, B4 |
| ETS1.C: Optimizing the Design Solution | A3, B4 |
| PS2.A: Forces and Motion | A1, A2, B1, B2, B3, C1, C2, C3 |

| NGSS Crosscutting Concepts | Marble Launcher Investigations |
|---|---|
| Cause and Effect | B1, C1, C2, C3 |
| Stability and Change | A1, A2, A3, B4 |
| Systems and System Models | B2, B3 |

# Common Core State Standards Correlations

| CCSS-Mathematics | | Marble Launcher Investigations |
|---|---|---|
| MP.2 | Reason abstractly and quantitatively. | A1, A2, A3, B1, B2, B3, C1, C2, C3 |
| MP.4 | Model with mathematics. | B1, B2, B3, B4, C1, C2, C3 |
| 6.EE.A.2 | Write, read, and evaluate expressions in which letters stand for numbers. | 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 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. | A1, A2 |
| 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. | A1, A2 |
| 7.SP.C.7 | Develop a probability model and use it to find probabilities of events. Compare probabilities from a model to observed frequencies; if the agreement is not good, explain possible sources of the discrepancy. | A3 |
| 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. | B1, B2, B3, C1, C2, C3 |
| HSN-Q.A.2 | Define appropriate quantities for the purpose of descriptive modeling. | B1, B2, B3, C1, C2, C3 |
| HSN-Q.A.3 | Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. | B1, B2, B3, C1, C2, C3 |
| HSA-CED.A.1 | Create equations and inequalities in one variable and use them to solve problems. | B1, B2, B3, C1, C2, C3 |
| 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. | B1, C1, C2, C3 |
| HSA-CED.A.4 | Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations. | B1, B2, B3, C1, C2, C3 |
| HSA-SSE.A.1 | Interpret expressions that represent a quantity in terms of its context. | B1, C1, C2, C3 |
| 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, C1, C2, C3 |
| 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. | B1, C1, C2, C3 |
| HSS-ID.A.1 | Represent data with plots on the real number line (dot plots, histograms, and box plots). | B1, C1, C2, C3 |

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# Common Core State Standards Correlations (cont'd)

| CCSS-English Language Arts & Literacy | | Marble Launcher Investigations |
|---|---|---|
| SL.8.5 | Integrate multimedia and visual displays into presentations to clarify information, strengthen claims and evidence, and add interest. | A3 |
| RST.6-8.3 | Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks. | A1, A2 |
| 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. | B1, C1, C2, C3 |
| 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, C1, C2, C3 |
| 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. | A1, A2 |
| WHST.11-12.9 | Draw evidence from informational texts to support analysis, reflection, and research. | B1, C1, C2, C3 |