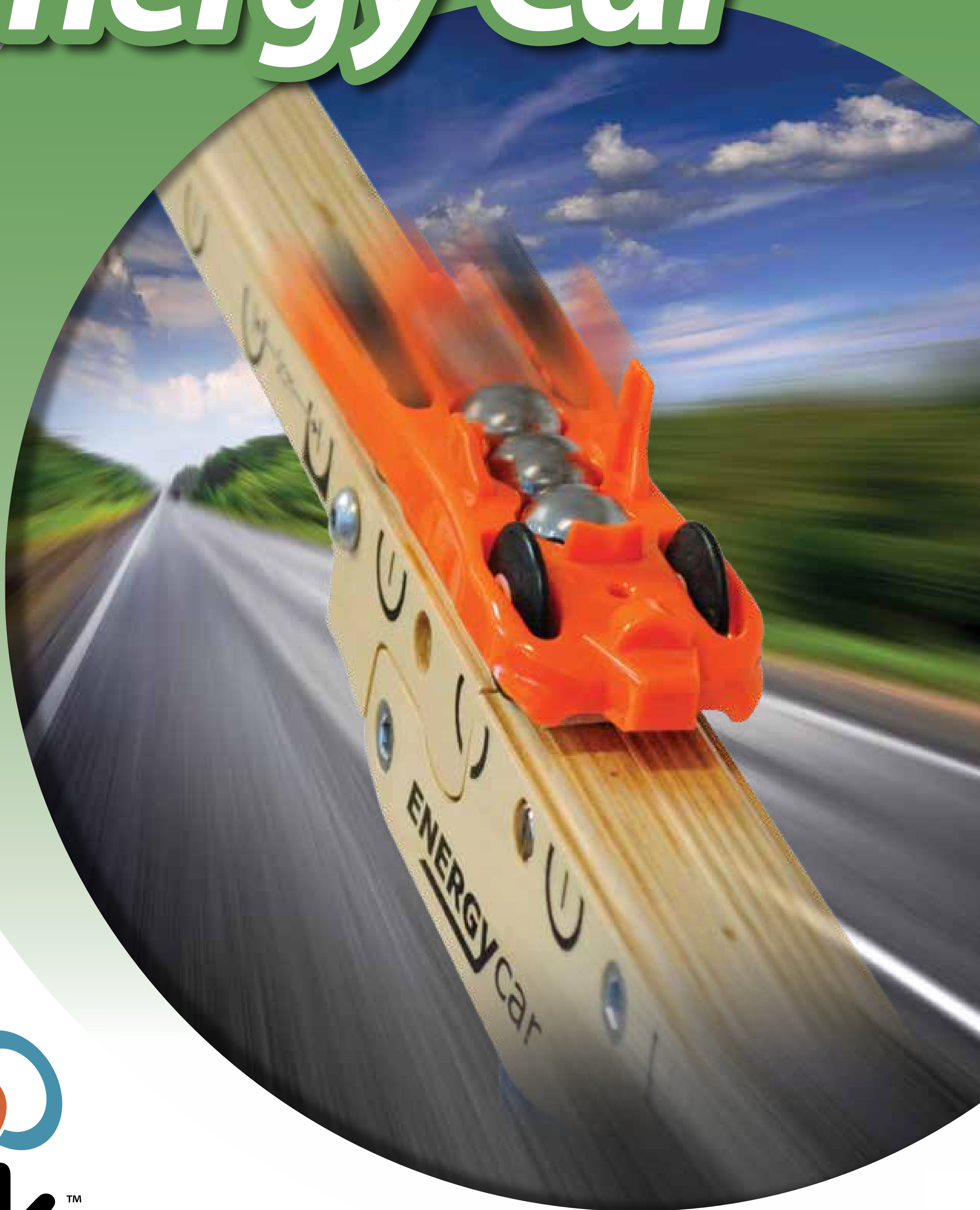
Motion, Force, and Energy

Energy Car



link™

CPO Science

Real Investigations in
Science and Engineering

Overview Chart for Investigations–Energy Car

	Investigation	Key Question	Summary	Learning Goals	Vocabulary
A1	Measuring Time Pages 1-6 45 minutes	How is time measured accurately?	Students learn how to use the DataCollector and photogates to accurately measure time.	• measure time accurately • convert between units of time • explain how a photogate works	reaction time time interval
A2	Experiments and Variables Pages 7-12 45 minutes	How do you design a valid experiment?	Students discover how variables affect a system. Students become familiar with the Energy Car, its components, and its setup.	• set up an experiment • explain the difference between control and experimental variables • discuss why conducting multiple experimental trials is better than gathering only one set of data	control variable experiment experimental variable trial variable
A3	Speed Pages 13-20 45 minutes	Can you predict the speed of the car as it moves down the track?	Students use the Energy Car to learn about speed. Students begin the investigation by making a prediction about what happens to the car's speed as it travels down an inclined track. After formulating hypotheses, students set up the experiment and test their predictions.	• predict what happens to the Energy Car's speed as the car travels down the track • create and interpret a speed vs. position graph • use a graph to make a prediction that can be quantitatively tested • calculate the percent error between a measurement and a prediction	average speed instantaneous speed speed
A4	Acceleration Pages 21-28 45 minutes	What is acceleration?	Students create a system that is designed to analyze the motion of the car as it moves down a hill. By creating and analyzing graphs of motion (position vs. time and speed vs. time), students are able to deduce the meaning of acceleration.	• define acceleration • analyze position vs. time and speed vs. time graphs to explain changes in motion of the Energy Car in terms of acceleration • apply the acceleration formula to solve problems	acceleration
A5	Friction Pages 29-36 90 minutes	How does friction affect motion?	Students conduct experiments using the Energy Car to observe the effects of air, rolling, and sliding friction. Students are able to observe the effects of increased air friction on the car by comparing speed data from the control and sail cars.	• observe the effects of air friction, rolling friction, and sliding friction • compare the effects of air, rolling, and sliding friction on an object's motion	air friction control variable deceleration force friction rolling friction sliding friction speed
A6	Newton's First and Second Laws Pages 37-44 90 minutes	What is the relationship between force and motion?	Students investigate Newton's first and second laws of motion. Based on their data, students will be able to infer how factors such as mass and force influence the motion of objects.	• describe how a net force impacts motion • explain the meaning of acceleration • use observations to interpret Newton's first and second laws of motion	acceleration Newton's first law Newton's second law

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A7	Newton's Third Law Pages 45-50 45 minutes	What happens when equal and opposite forces are exerted on a pair of Energy Cars?	Students set up two Energy Cars to study Newton's third law.	• explain the meaning of action-reaction forces • apply knowledge of Newton's first and second laws to explain the resulting force when objects experience equal and opposite forces • describe examples of Newton's third law	Newton's third law
A8	Collisions (STEM) Pages 51-58 45 minutes	Why do things bounce back when they collide?	Students examine collisions between cars of various mass. By observing the motion of the cars before and after each collision, students gather data to describe action and reaction forces.	• describe action-reaction force pairs • explain what happens when objects collide in terms of Newton's third law	Conservation of momentum momentum velocity
B1	Time, Distance, and Speed Pages 59-66 45 minutes	How is motion described and measured in physics?	Motion can be described by the distance an object moves in a given period of time. By observing changes in the variables of distance traveled and time elapsed, concepts such as acceleration and velocity can be described and analyzed.	• measure time intervals • calculate speed from time interval measurements • graph position vs. time for the Energy Car	average speed distance graph position speed *x*-axis *y*-axis
B2	Systems, Energy, and Change Pages 67-72 45 minutes	Why do things change? Why do things change by only a certain amount?	Students learn how to design and conduct an experiment using the Energy Car system. They identify and control variables, collect and analyze data, and explain their conclusions.	• calculate speed from time interval measurements • identify variables in an experiment • control variables in an experiment	distance energy experiment position speed system variable
B3	Newton's First Law Pages 73-78 55 minutes	Why are heavier objects harder to start moving or stop from moving?	Students explore the relationship between mass and inertia–Newton's first law.	• recognize that force is needed to change an object's motion • explain Newton's first law • describe how inertia and mass are related	inertia force mass Newton's first law weight

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	Investigation	Key Question	Summary	Learning Goals	Vocabulary
B4	Newton's Second Law Pages 79-84 55 minutes	What is force? What is the relationship between force and motion?	Students explore the relationship between force, mass, and acceleration. They set up an experiment, collect data, and use their data to derive the mathematical relationship discovered by Newton.	• define and calculate acceleration • explain the relationship between force, mass, and acceleration • determine mass, acceleration, or force given two of the quantities	acceleration deceleration Newton's second law
B5	Newton's Third Law Pages 85-90 55 minutes	What makes moving objects keep going at the same speed in the same direction?	Students investigate Newton's third law and conservation of momentum.	• use Newton's third law to explain various situations • explain the relationship between Newton's third law and momentum conservation • solve recoil problems	kinetic energy law of conservation of energy law of conservation of momentum momentum Newton's third law potential energy
B6	Collisions and Restraints (STEM) Pages 91-96 55 minutes	What is the best way to minimize forces during a collision?	Students explore the ways forces interact with an object during a collision. Students design solutions to control and minimize these forces.	• describe action-reaction force pairs • explain what happens when objects collide in terms of Newton's third law • apply the law of conservation of momentum when describing the motion of colliding objects	constraints criteria engineering cycle momentum law of conservation of momentum Newton's third law prototype trade-off
B7	Energy in a System Pages 97-100 45 minutes	How is energy related to motion?	Students set up the Energy Car system with one photogate and a rubber band. They use the data they record to explain how the motion of the car and its position are related to its energy.	• discuss the meaning of a system • describe the motion of the Energy Car in terms of energy • infer that objects possess either energy due to their position or energy due to their motion	energy joule (J) kinetic energy potential energy system
B8	Conservation of Energy Pages 103-108 45 minutes	What limits how much a system may change?	Students set up the Energy Car to collect data to determine the relationship between speed and drop height. Students then use their data to calculate potential energy and derive a new way to determine the speed of the car.	• analyze a speed vs. height graph • calculate potential energy • use energy conservation to derive a formula for the speed of the car in terms of energy	law of conservation of energy potential energy kinetic energy
B9	Energy and Efficiency Pages 109-114 45 minutes	How well is energy changed from one form to another?	Students compare the speed of a car after it collides elastically with a rubber band. Students use measurements of speed to determine the efficiency of energy transfer during these collisions.	• describe the transformations of energy that occur in a system • calculate the efficiency of energy transfer in a system	efficiency friction heat

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	Investigation	Key Question	Summary	Learning Goals	Vocabulary
C1	Work and Energy Pages 115-120 55 minutes	How does a system get energy?	Students use the Energy Car system to explore the concepts of work and energy.	• define work in terms of force and distance and in terms of energy • calculate the work done when moving an object • explain the relationship between work and power	work
C2	Motion on a Ramp (STEM) Pages 121-126 55 minutes	How does gravity work on a ramp?	Students take a closer look at motion on a ramp. Motion on a ramp is important in many ways. For example, highway engineers need to understand this kind of motion because hills that are too steep are dangerous. The angle of the ramp measures the steepness of the hill.	• calculate the steepness of a hill • analyze motion on a ramp • use Newton's second law to calculate force	acceleration acceleration due to gravity displacement displacement vector normal force vector
C3	Studying Two-Part Motion Pages 127-132 55 minutes	What happens to the Energy Car as it travels down a hill and across a flat section of track?	Students compare time and distance measurements to describe the changing speed and acceleration of the Energy Car as it accelerates and then moves at a constant speed.	• predict the effects of a ramp with sloped and level sections on acceleration and speed • observe the motion of an object • analyze the motion of an object in order to describe speed and acceleration in terms of distance and time	acceleration speed

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 Expectation	Investigations	NGSS Science and Engineering Practice	Investigations	NGSS Disciplinary Core Idea	Investigations	NGSS Crosscutting Concepts	Investigations
MS-PS2-1. Apply Newton's third law to design a solution to a problem involving the motion of two colliding objects.	A8	Constructing Explanations and Designing Solutions	A8, B6	PS2.A: Forces and Motion	A1-A8 B1-B6 C2, C3	Systems and System Models	A8, B6, B8, B9, C1
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, A3, A4, A5, A6, A7	Planning and Carrying Out Investigations	A1, A2, A3, A4, A5, A6, A7	PS2.B: Types of Interactions	B1, B4 C2, C3	Stability and Change	A1, A2, A3, A4, A5, A6, A7
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.	B4, C2, C3	Analyzing and Interpreting Data	B4, C2, C3	PS3.A Definitions of Energy	B7, B8, B9 C1	Cause and Effect	B4, B6, 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.	B1, B2, B3, B5	Using Mathematics and Computational Thinking	B1, B2, B3, B5, B8, B9 C1	PS3.B Conservation of Energy and Energy Transfer	B8, B9 C1	Energy and Matter	B6, B7, B9
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.	B6						
HS-PS3-1. Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known.	B7, B8, B9, C1						

Common Core State Standards Correlation

CCSS-Math	Investigations
6.EE.A.2 Write, read, and evaluate expressions in which letters stand for numbers.	A3, A4, A6, A8
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.	A3, A4, A6, A8
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, A6, A8
MP.2 Reason abstractly and quantitatively.	A3, A4, A6, A8
MP.4 Model with mathematics.	A3, A4, A6, A8
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-B9 C1-C3
HSA-SSE.A.1 Interpret expressions that represent a quantity in terms of its context.	B1-B5, B7, B8 C1-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.	B3-B5
HSA-CED.A.1 Create equations and inequalities in one variable and use them to solve problems.	B3-B5 C2
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.	B4, B8 C1-C3
HSA-CED.A.4 Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations.	B1-B5, B7, B8 C1-C3
HSF-IF.C.7 Graph functions expressed symbolically and show key features of the graph, by hand in simple cases and using technology for more complicated cases.	C1-C3
HSS-IS.A.1 Represent data with plots on the real number line (dot plots, histograms, and box plots).	B4, B8 C1-C3

CCSS-Literacy	Investigations
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.	A2, A8
RST.6-8.3 Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks.	A1-A8
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.	B3
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.	B6
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.	B3-B5 C1, C2
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.	B6