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Forces and Motion (PS2): An Integrated K–8 Hands-On Approach Supporting the NGSS and CCSS ELA

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An Integrated K–8 Hands-On Approach Supporting the *NGSS* and *CCSS ELA*

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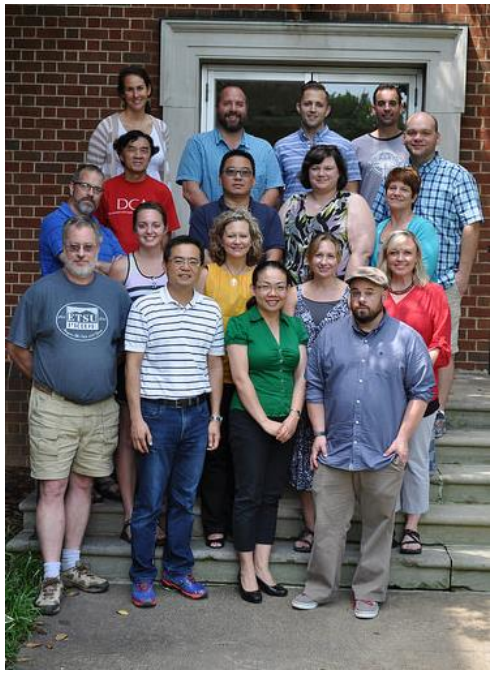
Preparing College/Career Readiness through Integrating Science Learning with Literacy in Grades 6-12

A LEA-ETSU-Business Partnership Initiative Supported by TN DOE MSP and THEC ITQ Grants (2015-17)



Local Education Agents

Bristol City Schools

Greeneville City Schools

Kingsport City Schools

Sullivan County

Unicoi County Schools

Washington County Board of Education

Institute of Higher Education

East Tennessee State University

ETSU Northeast Tennessee State Innovation Hub

Business Partners

CooperStandard

Domtar

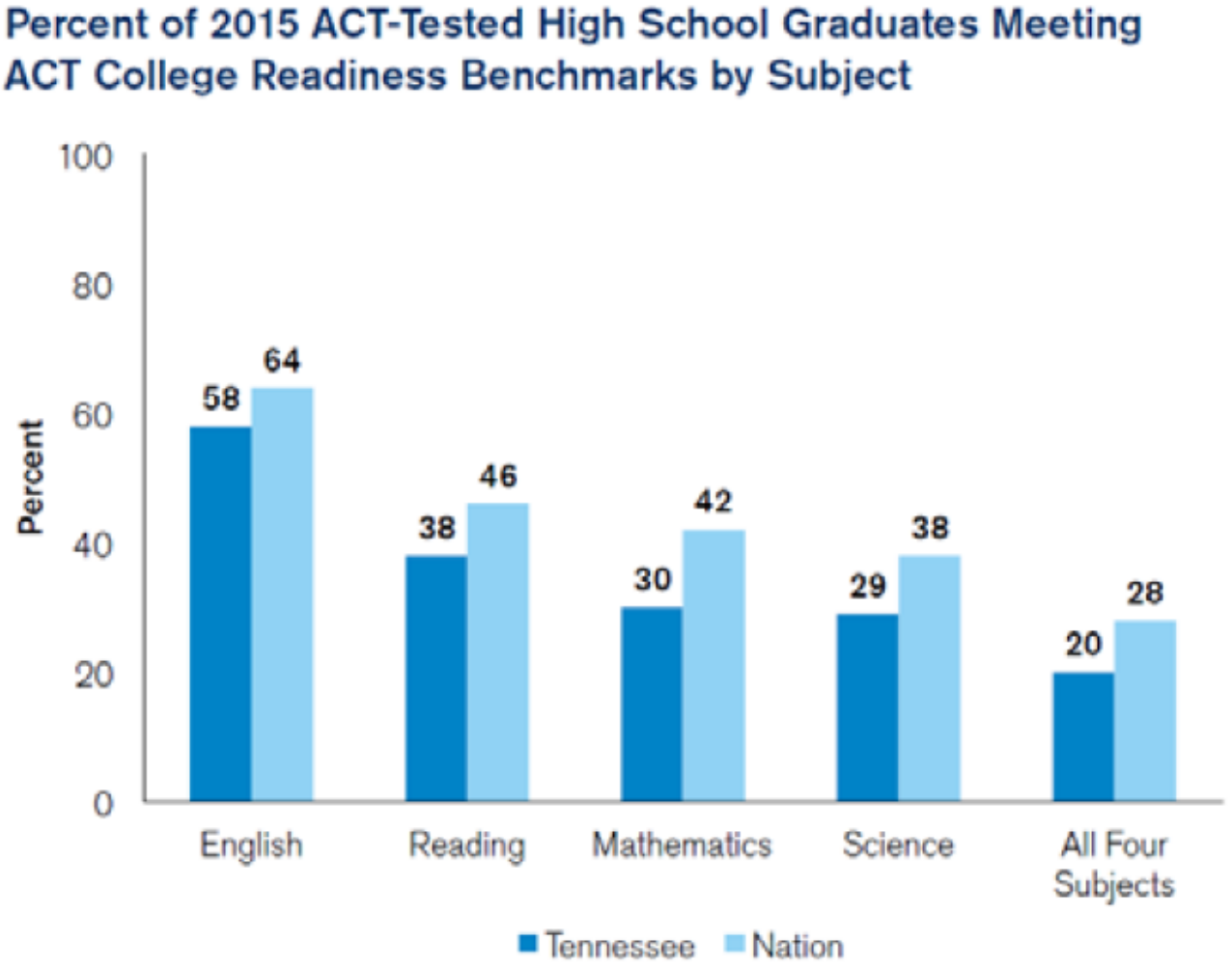
NFS Nuclear Fuel Services, Inc.

ZF TRW

Wellmont Health System

East Tennessee State University

Picture of College Readiness



Research Questions

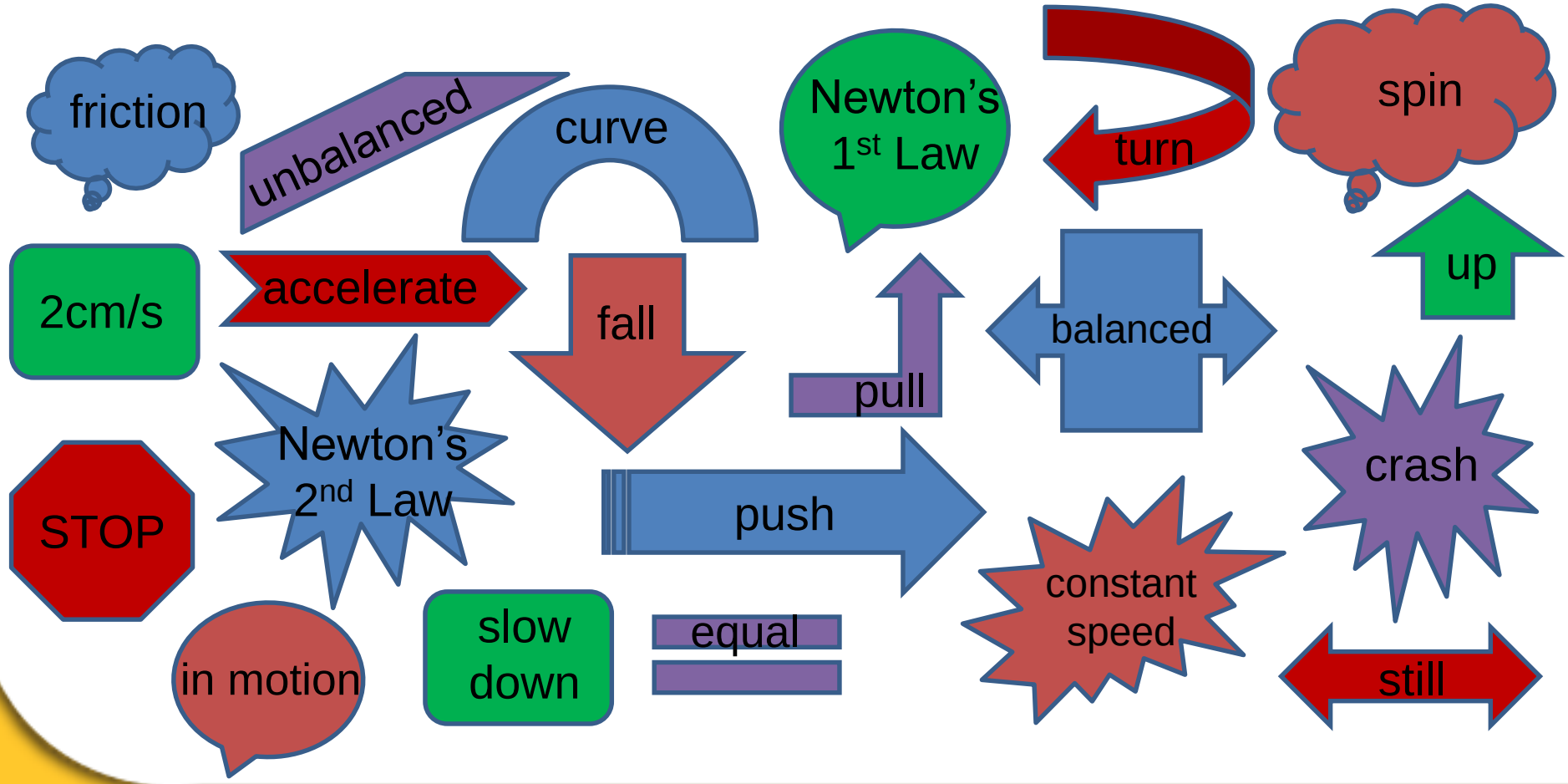
- **RQ1**: How does cross-discipline instruction benefit and enrich each subject discipline?
- **RQ2**: How does integration of science learning with literacy in G6-12 impact college/career readiness?

Word/Phrase Splash

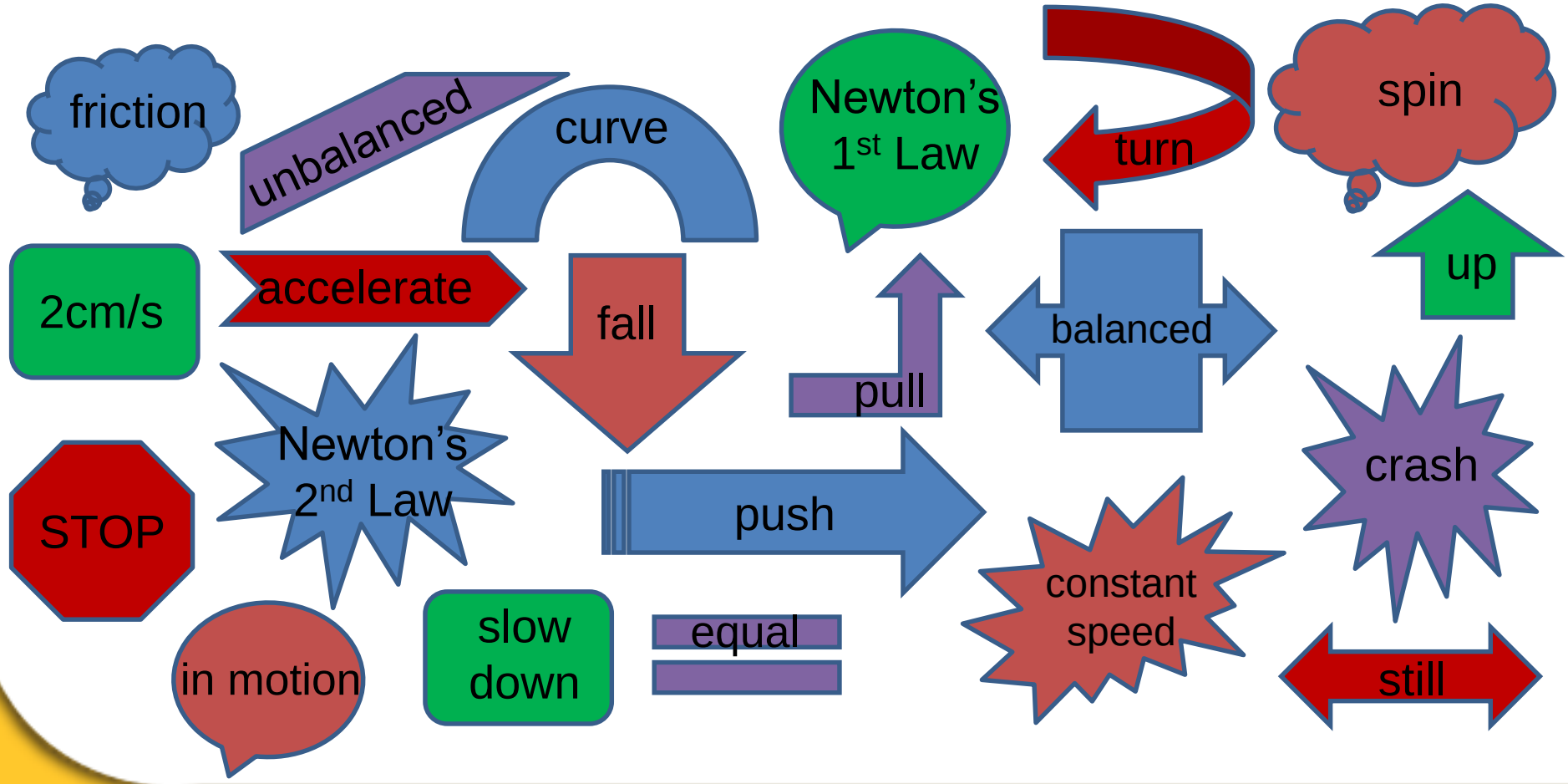
Word Splash is a comprehension and vocabulary strategy that makes learning terminology easier for students. It's a fun, interactive activity that engages and motivates students to learn new words while setting a clear purpose for reading (Burns, 2006).

- Interest Topics/bags-
- Star Wars
- Nature
- Construction
- Sports
- The Arts
- Aviation
- Cars and Racing
- Disney Princess

Use the materials in your bag to demonstrate the words that you find.



Sort the words into two categories: balanced forces & unbalanced forces.



Which claims about balanced and unbalanced forces can be supported with evidence?

Claim 1	Claim 2
Balanced = not moving Unbalanced = moving	Balanced = no change in motion Unbalanced = change in motion
Claim 3	**Claim 4**
Balanced = zero net force Unbalanced ≠ zero net force	Balanced = Newton's 1st Law Unbalanced = Newton's 3rd Law

3rd Grade
NGSS & Common Core Integration

NGSS	Common Core
3-PS2-1. Plan and conduct an investigation to provide evidence of the effects of balanced and unbalanced forces on the motion of an object.	RI.3.1 Ask and answer questions to demonstrate understanding of a text, referring explicitly to the text as the basis for the answers. (3-PS2-1),(3-PS2-3)
	W.3.7 Conduct short research projects that build knowledge about a topic. (3-PS2-1),(3-PS2-2)
3-PS2-2. Make observations and/or measurements of an object's motion to provide evidence that a pattern can be used to predict future motion.	W.3.8 Recall information from experiences or gather information from print and digital sources; take brief notes on sources and sort evidence into provided categories. (3-PS2-1),(3-PS2-2)

Middle School
NGSS & Common Core Integration

NGSS	Common Core
MS-PS2-1. Apply Newton's Third Law to design a solution to a problem involving the motion of two colliding objects.*	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 (MS-PS2-1),(MSPS2-3)
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.	RST.6-8.3 Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks. (MS-PS2-1),(MS-PS2-2),(MS-PS2-5)
	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. (MS-PS2-1),(MS-PS2-2),(MS-PS2-5)

Kinesthetic Learning

- Acting out Newton's Laws of Motion

First Law
Objects at rest remain at rest and objects in motion remain in motion in a straight line unless acted upon by an unbalanced force.

Second Law
Force equals mass times acceleration (or $f = ma$).

Third Law
For every action there is an equal and opposite reaction.


SECTION 1
FORCES THAT MOVE US
Super Scientist Max Axiom jumps right into the world of forces and motion at an amusement park.
What a perfect day . . .
SKRAWW!
. . . even though everything feels turned upside down.
Spinning, flying, jumping, and falling are just some of the amazing ways to move.
But there's a lot of science behind the zoom-zoom around us.
In fact, the world is full of all kinds of motion.
Everything that moves needs a force to get it moving.
Back for another jump, already?
You bet!
A force is any push or pull on an object. Bungee jumping depends on a force called gravity.
It pulls objects toward each other, and it keeps us on the earth.
Gravity is the reason I fall down, not up or sideways.

Graphic Texts

Readwritethink.org:

1) Comic Book Primer
2) Graphic Novel Terms
3) Comic Book Scripting Techniques
4) Sample Comic Book Script
5) Comic Book Creator Resource

MS-PS2 Motion and Stability: Forces and Interactions

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 *(MS-PS2-1),(MS-PS2-3)*
RST.6-8.3	Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks. *(MS-PS2-1),*(MS-PS2-2),*(MS-PS2-5)*
WHST.6-8.1	Write arguments focused on *discipline-specific content.* (MS-PS2-4)
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. *(MS-PS2-1),*(MS-PS2-2),*(MS-PS2-5)*
Mathematics –	
MP.2	Reason abstractly and quantitatively. (MS-PS2-1),(MS-PS2-2),(MS-PS2-3)
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. (MS-PS2-1)
6.EE.A.2	Write, read, and evaluate expressions in which letters stand for numbers. *(MS-PS2-1),(MS-PS2-2)*
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. *(MS-PS2-1),(MS-PS2-2)*
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. *(MS-PS2-1),(MS-PS2-2)*

MS-PS2 Motion and Stability: Forces and Interactions

MS-PS2 Motion and Stability: Forces and Interactions

Students who demonstrate understanding can:

MS-PS2-1. **Apply Newton's Third Law to design a solution to a problem involving the motion of two colliding objects.*** [Clarification Statement: Examples of practical problems could include the impact of collisions between two cars, between a car and stationary objects, and between a meteor and a space vehicle.] [Assessment Boundary: Assessment is limited to vertical or horizontal interactions in one dimension.]

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.** [Clarification Statement: Emphasis is on balanced (Newton's First Law) and unbalanced forces in a system, qualitative comparisons of forces, mass and changes in motion (Newton's Second Law), frame of reference, and specification of units.] [Assessment Boundary: Assessment is limited to forces and changes in motion in one-dimension in an inertial reference frame and to change in one variable at a time. Assessment does not include the use of trigonometry.]

MS-PS2-3. **Ask questions about data to determine the factors that affect the strength of electric and magnetic forces.** [Clarification Statement: Examples of devices that use electric and magnetic forces could include electromagnets, electric motors, or generators. Examples of data could include the effect of the number of turns of wire on the strength of an electromagnet, or the effect of increasing the number or strength of magnets on the speed of an electric motor.] [Assessment Boundary: Assessment about questions that require quantitative answers is limited to proportional reasoning and algebraic thinking.]

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.** [Clarification Statement: Examples of evidence for arguments could include data generated from simulations or digital tools; and charts displaying mass, strength of interaction, distance from the Sun, and orbital periods of objects within the solar system.] [Assessment Boundary: Assessment does not include Newton's Law of Gravitation or Kepler's Laws.]

MS-PS2-5. **Conduct an investigation and evaluate the experimental design to provide evidence that fields exist between objects exerting forces on each other even though the objects are not in contact.** [Clarification Statement: Examples of this phenomenon could include the interactions of magnets, electrically-charged strips of tape, and electrically-charged pith balls. Examples of investigations could include first-hand experiences or simulations.] [Assessment Boundary: Assessment is limited to electric and magnetic fields, and limited to qualitative evidence for the existence of fields.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education:*

Science and Engineering Practices

Asking Questions and Defining Problems
Asking questions and defining problems in grades 6–8 builds from grades K–5 experiences and progresses to specifying relationships between variables, and clarifying arguments and models.
- Ask questions that can be investigated within the scope of the classroom, outdoor environment, and museums and other public facilities with available resources and, when appropriate, frame a hypothesis based on observations and scientific principles. (MS-PS2-3)

Planning and Carrying Out Investigations
Planning and carrying out investigations to answer questions or test solutions to problems in 6–8 builds on K–5 experiences and progresses to include investigations that use multiple variables and provide evidence to support explanations or design solutions.
- Plan an investigation individually and collaboratively, and in the design: identify independent and dependent variables and controls, what tools are needed to do the gathering, how measurements will be recorded, and how many data are needed to support a claim. (MS-PS2-2)
- Conduct an investigation and evaluate the experimental design to produce data to serve as the basis for evidence that can meet the goals of the investigation. (MS-PS2-5)

Constructing Explanations and Designing Solutions
Constructing explanations and designing solutions in 6–8 builds on K–5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with scientific ideas, principles, and theories.
- Apply scientific ideas or principles to design an object, tool, process or system. (MS-PS2-1)

Engaging in Argument from Evidence
Engaging in argument from evidence in 6–8 builds from K–5 experiences and progresses to constructing a convincing argument that supports or refutes claims for either explanations or solutions about the natural and designed world.
- Construct and present oral and written arguments supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon or a solution to a problem. (MS-PS2-4)

Connections to Nature of Science

Scientific Knowledge is Based on Empirical Evidence
- Science knowledge is based upon logical and conceptual connections between evidence and explanations. (MS-PS2-2),(MS-PS2-4)

Disciplinary Core Ideas

PS2.A: Forces and Motion
- For any pair of interacting objects, the force exerted by the first object on the second object is equal in strength to the force that the second object exerts on the first, but in the opposite direction (Newton's third law). (MS-PS2-1)
- The motion of an object is determined by the sum of the forces acting on it; if the total force on the object is not zero, its motion will change. The greater the mass of the object, the greater the force needed to achieve the same change in motion. For any given object, a larger force causes a larger change in motion. (MS-PS2-2)
- All positions of objects and the directions of forces and motions must be described in an arbitrarily chosen reference frame and arbitrarily chosen units of size. In order to share information with other people, these choices must also be shared. (MS-PS2-2)

PS2.B: Types of Interactions
- Electric and magnetic (electromagnetic) forces can be attractive or repulsive, and their sizes depend on the magnitudes of the charges, currents, or magnetic strengths involved and on the distances between the interacting objects. (MS-PS2-3)
- Gravitational forces are always attractive. There is a gravitational force between any two masses, but it is very small except when one or both of the objects have large mass—e.g., Earth and the sun. (MS-PS2-4)
- Forces that act at a distance (electric, magnetic, and gravitational) can be explained by fields that extend through space and can be mapped by their effect on a test object (a charged object, or a ball, respectively). (MS-PS2-5)

Crosscutting Concepts

Cause and Effect
- Cause and effect relationships may be used to predict phenomena in natural or designed systems. (MS-PS2-3),(MS-PS2-5)

Systems and System Models
- Models can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy and matter flows within systems. (MS-PS2-1),(MS-PS2-4),

Stability and Change
- Explanations of stability and change in natural or designed systems can be constructed by examining the changes over time and forces at different scales. (MS-PS2-2)

Connections to Engineering, Technology, and Applications of Science

Influence of Science, Engineering, and Technology on Society and the Natural World
- The uses of technologies and any limitations on their use are driven by individual or societal needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions. (MS-PS2-1)

Connections to other DCIs in this grade-band: **MS.PS3.A** (MS-PS2-2); **MS.PS3.B** (MS-PS2-2); **MS.PS3.C** (MS-PS2-1); **MS.ESS1.A** (MS-PS2-4); **MS.ESS1.B** (MS-PS2-4); **MS.ESS2.C** (MS-PS2-2),(MS-PS2-4)

Articulation across grade-bands: **3.PS2.A** (MS-PS2-1),(MS-PS2-2); **3.PS2.B** (MS-PS2-3),(MS-PS2-5); **5.PS2.B** (MS-PS2-4); **HS.PS2.A** (MS-PS2-1),(MS-PS2-2); **HS.PS2.B** (MS-PS2-3),(MS-PS2-4),(MS-PS2-5); **HS.PS3.A** (MS-PS2-5); **HS.PS3.B** (MS-PS2-2),(MS-PS2-5); **HS.PS3.C** (MS-PS2-5); **HS.ESS1.B** (MS-PS2-2),(MS-PS2-4)

Common Core State Standards Connections:
ELA/Literacy –

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice or Disciplinary Core Idea.

Student Engagement Based on Fourfold Interests

- **Language instinct**: conversation personal interaction, and communication
- **Instinct of making/Constructive impulse**: expression in play, movement, gesture, make believe, seeking outlet in shaping materials into tangible forms and permanent embodiment.
- **Instinct of investigation**: grow out of the combination of the constructive impulse with the conversational.
- **Expressive impulse/art instinct**: grow out of the communicating and constructive instincts, refinement, full manifestation.

- Dewey, J. (2013). *The school and society and the child and the curriculum*. University of Chicago Press.

Newton's Three Laws of Motion

	Formula	Keywords/ Logic argumentation	Hands-on Activities
First Law	$\Sigma F = 0$	**Keywords:** Force: Balanced forces/ zero net forces Motion.: Inertia of motion (Status quo) **Argumentation:** Balanced net forces ⇒ constant motion (velocity = direction + speed)	• Wine glasses with different papers • Wine glasses with coins, paperboard
Second Law	$\Sigma F \neq 0$	**Keywords:** Force: Unbalanced forces/ non-zero net forces Motion: Change of motion **Argumentation:** Unbalanced net forces ⇒ motion change (direction and/or speed). The change also is proportional to mass.	• Motion detector- position, velocity, acceleration, time • Motion encoder system
Third Law	F_{action} $-F_{reaction}$	**Keywords:** F: Forces occur in pair Motion: Action on an object and Reaction on a subject **Argumentation:** Action is performed ⇒ reaction exists simultaneously equal in magnitude and opposite in direction.	• Balloon Jet activities • Skating board activities

Hands-on Activities for Newton's Three Laws

A. First Law

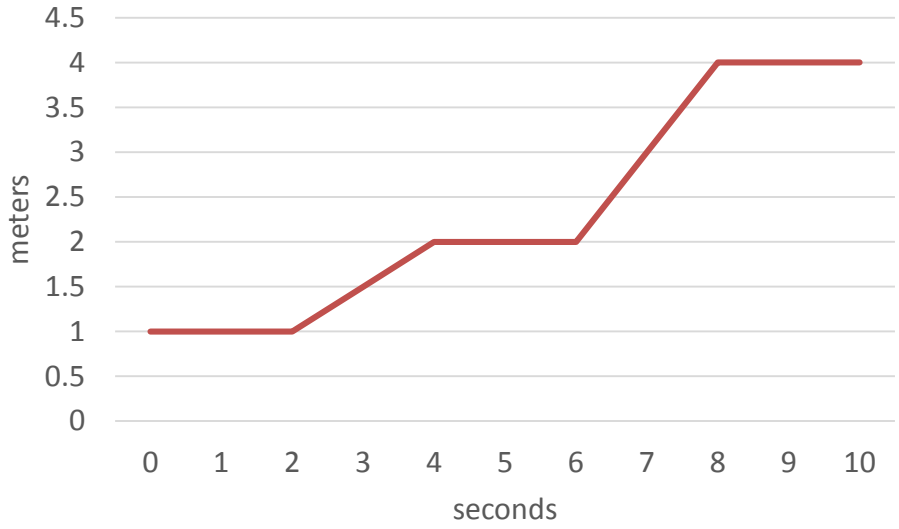
1. Wine glasses with different papers
2. Wine glasses with coins, paperboard

Hands-on Activities for Newton's Three Laws

B. Second Law

1. Motion detector: **position**, velocity, acceleration, **time**

Task one: Describe the movement and perform it.



Task Two:

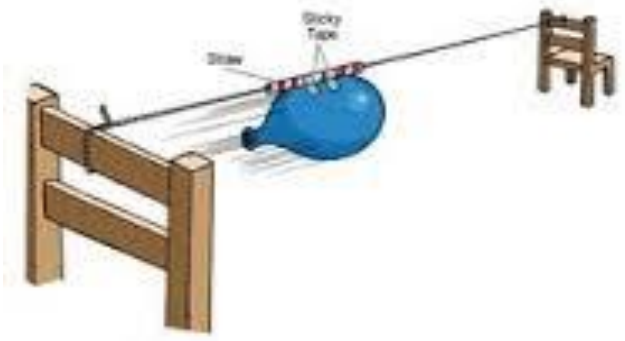
Draw a diagram and perform it: *You start standing close to the device. Hold 3 seconds. Walk 3 meters away from the device for 3 seconds. Hold for another 3 seconds, and then walk 2 meters away from the device for another 3 seconds.*

2. Motion encoder system for more precise experiments

Hands-on Activities for Newton's Three Laws

C. Third Law

1. Balloon Jet activities



<u>Project-based Approach:</u>

1. Design a team recipe about how to make a balloon move as far as possible (identify variables, procedures)
2. Measure an average speed in your experiment setting
3. Describe how speed would change during your experiment setting
   Limitation: move your balloon horizontally

2. Skating board activities (Prediction-Observation-Explanations)

- You **push** a wall
- You and your teammate **push each other**
- You **push** your teammate but she/he **doesn't push** you.
- You **pull** your teammate (with a rope) but she/he **does nothing**.

What is Newton's Mind/ Best for Newton's Laws

Two Big Picture Questions:

1. Why **THREE**?
   Is it a complete set of (hypothetical) theories / (empirical) laws that can describe **forces and motion on an object**?

2. $\Sigma F = 0$
   $\Sigma F \neq 0$
   F_{action} and $-F_{reaction}$

Should we start from scientific definitions or should we start from hands-on activities?

Implications of Newton's Third Law

For any pair of interacting objects, the force exerted by the first object on the second object is equal in strength to the force that the second object exerts on the first, but in the opposite direction (Newton's third law). (MS-PS2-1)

Let's think about a concept of LOVE.

Love is an art of loving and being loved.

Keyword: ?

Interaction!

Questions?