Unit Title:

Paper-fold Physics: Newton's Three Laws of Motion

Lisa (Yuk Kuen) Yau

Revised Date: Monday, July 30, 2018

1. Abstract

Can you teach physics effectively using only paper and the simple act of folding? This interdisciplinary curriculum unit is designed for a 5th grade class focusing on how to unpack Newton's Three Laws of Motion using paper folding (i.e. origami) as a teaching tool to promote inquiry and project-based learning. Students will learn scientific concepts by making paper models, testing them to form hypotheses, analyzing the collected data with graphs, researching supporting theories of Newton, making real-world connections, writing scientific conclusions, and applying their new understandings to solve challenges such as how to design a paper container to protect a fragile egg from cracking under a stressful landing.

Can paper folding be a teaching strategy to promote an equitable and competitive learning environment for all students from the hyperactive to the hypersensitive, from the "underachievers" to the "overachievers", and all other biased labels in between? Folding in solitude is a calming activity that builds concentration and focus (i.e., mindfulness), allows each student multiple opportunities to fail and succeed. In the repeating actions of folding in order to gain mastery, student can retain the learned knowledge better and longer. From my own experience, I have witnessed how powerful origami can help students to verbalize what they are learning to each other. Students gain a better sense of self and community as they make personal connections to real problems and situations with their hands "thinking out loud." Of course, origami is not the magic pill but if uses properly, it can open many doors of positive learning for both students and teachers from all walks of life.

Rationale: I can name three unique problems that limit a teacher's overall effectiveness.

Problem #1 (Compartmentalized vs. Interdisciplinary Approach): Elementary teachers are often mandated to teach each subject in isolation. There are the usual daily 90 minutes Math block, 120 minutes ELA block and the leftover time is for Science, Social Studies, and everything else like nutrition, moral and career education. In Pennsylvania, elementary teachers (from 3rd to 8th Grades) are held accountable for how their students perform in the Math and ELA standardized tests. 4th Grade and 8th Grade teachers are responsible for the Science test scores. For young children, this compartmentalized approach in separating each subject in different time blocks has more negative than positive impacts on how students view, evaluate and connect knowledge to the real world. It also underestimates the potentials of the human brain to develop and make complex connections based on unifying concepts. While teachers are getting an increased amount of curriculum responsibilities year after year, the school hours stay the same, forcing teachers to have to do more with less time. One effective solution is the word "integration."

I believe origami can be a unique engine to integrate the teaching of science, technology, reading & writing, engineering, art, and math (STREAM) to save time as well as to blend these interdisciplinary subjects to better serve student learning. I agreed that no one but maybe a handful of people on Earth are good at everything. However, I also believe our educational system at the elementary levels can nurture children to acquire multiple intelligences by exposing them to as many transferrable skills as possible. Furthermore, the more I can connect my students with as many subjects in their learning, the more creative I become and the more creative they become. When I am teaching science and math, I also teach reading, writing, speaking and listening. It's time to break down these "subject siloes."

In recent years, Finland, often considered as a global education leader, has shifted from the "traditional teaching by subjects" system to focus on "teaching by topics or themes." Some called it "phenomenon" teaching. Because lessons in Science are revisited and reinforced by activities in Math, ELA and Art, students have more opportunities to be able to comprehend, retain, and assimilate difficult concepts. In higher education, online websites like Coursera is working with the Museum of Modern Art (MoMA) in offering courses to explore Art & Idea with themes like Places & Spaces, Art & Identity, Transforming Everyday Objects, and Art & Society. In addition, e-learning, emerging technology and the virtual classrooms are moving education to embrace the benefits of ubiquitous learning (learning anywhere, anytime and everywhere) which supports active knowledge making and differentiated learning. The massive number of origami tutorial videos can show anyone who wants to learn how to fold any objects from the basic crane to complex sculptures like dragons and phoenixes. Can a piece of paper and the act of folding also achieve these impacts of e-Learning? You can manage to find a piece of paper almost anywhere and anytime.

I believe students in this new framework of ubiquitous learning would be more involved in planning and assessing their own learning which in turn, encourages students to take ownership and set more lofty yet achievable goals. I think origami can bridge ubiquitous learning from different disciplines demanded of our students on a daily basis. Teachers can cultivate the Modern Renaissance Child, the universal learner, the polymath inside their students at an early age. Our collective goals in the elementary schools need to change to the philosophy of "learn more through integration" rather than "learn one standard at a time." In addition, teachers are challenged to remain curious themselves as they learn new knowledge and new methods to solve problems in our ever-changing world. This framework will not water down the demands of standards, but rather approach these standards with layers of complexities.

Problem #2 (Left v. Right Brain): From my own teaching experience, each year I would have a group of students who claimed themselves as artists and a different group of students who claimed themselves as good in math. I believe students have been conditioned to think of themselves to be good at one thing but not the other. Recent neuroscience studies are debunking the "neuromyth" that learners are either more left-brain or right-brain dominant. It's silly to think that each of us only use half of our brains more often than the other half. This phenomenon may also have been the result of traditional schools tend to focus on the left-brain modes of thinking with emphasis on objective, sequential, logical, analytic and rational academic subjects. On the other hand, our education system downplays the right-brain ways of thinking by justifying "true learning" cannot be subjective, intuitive, illogical, synthesizing and holistic. Who has time to promote illogical thinking? If a lesson is not timed and written down with clear objectives, it cannot be a good lesson. Or can it?

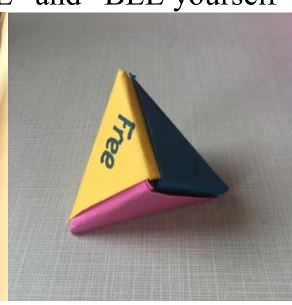
Another neuromyth related phenomenon manifests itself in my students' handwriting. Because fine motor skills are not being reinforced and handwriting is not being taught explicitly in elementary school, each year I have at least three 5th grade students whose handwriting is completely illegible, another three students who print letters as big as those of a kindergartener, and another three students who write so tiny that it makes me ponder if their handwriting is an indicator of low self-esteem as well as the uncertainty of their own unique voice and identity. In addition, another three students lack the fine motor skills to draw and cut straight lines. That's an estimated total of at least 12 out of the usual 30 students, or approximately 40% of the class, who have not taken advantages of learning by doing. Writing by hand is becoming less important since the introduction of laptops, chromebooks and iPads in my classroom. With the release of iPhones in 2007, almost all of my upcoming students (the Generation Z) have texted messages using their two thumbs, but these same students have never been taught how to write in cursives and use handwriting as an art form (calligraphy) for self-expression.

Possible Solution: Paper-folding can teach students how to use their hands to manipulate concepts, in turn, giving all children but especially the tactile-inclined and spatial-gifted students a fun and creative opportunity to shine. At the same time, I believe origami can improve mindfulness, focus and concentration in all children including those who are labeled hyperactive or too difficult to teach. What happens when we test the cliché "thinking outside the box" or "thinking outside of a square" by manipulating paper *inside a square*? My curriculum unit advocates a more whole-brained mode of learning. I hope to set a precedent to erase the neuro-myth of left and right brains learning in my own classroom.

Problem #3 (Ineffective Math Instructions): Each year about 75% of my entering 5th grade students struggle with how to add and subtract fractions, and about 50% expressed that because math is getting more and more complicate, they don't really like it anymore. From personal experiences, children love origami while most adults are skeptical of its value. When I tell adults that I use paper-folding to teach fractions, there are two typical responses: 1) "Really? That's so cute and adorable." 2) "Origami? That's too difficult for me." In my opinion, the first response is a nice, (most likely unintentional) backhanded compliment suggesting origami is a bit childish, and the second response is an admission that origami can be challenging and it demands discipline. Recently origami has become less a child play activity as more . There is an emerge of prominent origami experts a background in math, science, engineering, technology, and/or architecture. They value creativity as much as they value the hidden rules of folding. If there are rules to origami, then anyone who can follow these rules can also master origami.

In contrast, whenever I introduce origami to children of any age (say from ages 5 to 14), nine out of ten times, their eyes would widen, their hands start moving, and their voices echo these words: “Teach me! Teach me!” I have found that students who use origami to learn math have good number sense and often perform better in the standardized tests. Paper-folding is an untapped resource for supplementing math instruction; it may even improve math instruction by increasing student engagement. Can paper-folding boost memory and help students to master their conceptual understanding of math ideas as well as other subjects? I think origami is a great engine to support “schematic learning” with repeated failures and successes.

Below are photos of my former 5th grade students (FY 2017-2018) arranging their origami gift boxes to prepare for an oral presentation. On May 23, 2018, four of my students accompanied me to the Need in Deed Shout Out Celebration at the University of the Arts. Need in Deed is a Philadelphia-based service learning program designed to promote student’s voice. My students created 3 distinct boxes and send heartfelt messages to address the social issue of Kids Home Alone: 1) a cube with the message “You are not alone!” on an origami ring; 2) a rectangular prism with the message “Show love to someone who might need it today” on an origami heart 3) a tetrahedron with the messages “FREE” and “BEE yourself” on a yellow origami bee.

General Inquiries and Possible Solutions:

1) How can origami transforms the teaching of math? A folded model is composed of geometric properties and math relationships. A crane unfolded provides a crease pattern filled with concepts of fractions and equations. Origami can also be used to teach perimeter, area, volume, and other number relationships. Origami models set a tangible stage for students to discuss geometric properties. Student can identify math relationships in a given origami model by using addition, subtraction, multiplication and division to problem-solve.

2) How can origami develop scientific thinking in students? Action origami can deepen the understanding of Newton’s Laws of Motion in many fun and creative ways. Teachers had written lessons using origami animals like jumping frogs to demonstrate the laws of physics. A spider origami model can illustrate how its anatomy is divided into 2 regions called cephalothorax and abdomen for a unit on Ecosystem. Origami written instructions and tutorial videos are great venues for students to practice their abilities as they follow the instruction step by step through visual representations.

3) How can origami engineering sparks creative play leading to innovation? Art is a great platform for free thinking and aesthetic pleasures. Creativity is often a messy process of failed attempts. Origami can be used to structure lessons to allow a wide range of freedom with a razor-focus goal to innovate designs that is functional as well as elegant. Students can be challenged to identify global problems by creating origami inventions.

Additional Rationale as to Why Use Origami to Teach: Science materials can be costly. Physicist Manu Prakash and his team remarkably created a 50-cent microscope made of paper that is easy to made and easy to use; he believes this invention can revolutionize healthcare in developing countries. So what if you can conduct a series of low-cost experiments to test the theories of forces and motion with only paper? In Ancient China and Japan, paper was scarce and reserved only for the elites and religious reasons. For centuries, Japan has used recyclable, renewable and natural materials like paper, leaves, bamboo and grass for packaging everyday items like eggs and fruits. Today paper is easily accessible and comes in a variety of dimension, thickness, color and decorative designs. As people become more environmental friendly, paper is now recycled, remade and reused. One day in the future, paper may once again become a rarity, because computer will eventually replace textbooks, and deforestation will destroy more trees than we can plant new replacements.

Because origami tends to lead to minimalistic designs that are clear, simple and aesthetic pleasing to the eyes, it inherently follows many characteristics of good design. According to Dieter Rams (a German industrial design and retired academic), good design is innovative, aesthetic, unobtrusive, honest, long-lasting, environmentally friendly, thorough down to the last detail, makes a product useful and understandable. Lastly, good design "involves as little design as possible." Dieter Rams' ten principals of good design and the characteristics of origami favor a "less is better" philosophy. Folding a blank piece of paper is "creating something out of nothing" and the sky is the limits.

Background

Riddle: "Open, it stretches; closed, it rolls up. It can be contracted or expanded; hidden away or displayed." – *Fu Xian* 傅咸 (239–294), zi Changyu 長虞 **Answer:** Paper

"To most, the real beauty of origami lies in its simplicity, allowing everyone to create their interpretation of the world in paper."– Vanessa Gould, director, *Between the Folds*

"Even DNA is folded—you and I are born from folding."– Paul Jackson, origami artist.

My Personal Experiences: As a child growing up in Hong Kong (the then British controlled-colony), paper folding was a shared hobby for all elementary classmates. I immigrated to the United States at the age of eleven (in 1977), folding paper cranes, cameras, gift boxes and other playful objects was one of my favorite pastimes. 折纸 Zhézhǐ (Chinese Mandarin pinyin) or zip^{3}zi^2 (Chinese Cantonese jyutping), the art of paperfolding was a healthy recreational obsession as well as a dexterous-gymnastics mind game of my childhood. As a child, I was unaware that the Japanese term origami (ori = to fold and kami = paper) was the more popular name known to the world until I was an adult, a college student majoring in art and architecture. Suddenly, origami is not just child play; it harbors and anchors an educational importance in exploring innovative ideas in art and architecture. Ever since my college years (1985 to 1989), I have continued to learn about origami through personal research with reading of theories and practices. The provocative 1994 book titled "Origami from Angelfish to Zen" by Peter Engel (a writer and an architect) introduces me to how origami can be linked uniquely with mathematics, history, art as well as the theories and practices of Japan's legendary masters such as Akira Yoshizawa.

Brief History of Paper and Origami: Paper was invented in China around 105 A.D and was used mainly for religious ceremonies as a luxury item. Monks brought paper to Japan in the 6th century and later during the Edo period (1603 to 1886) origami became recreational as well as ceremonial. Europe also has a tradition of paper folding dated back to the 12th century with the Moors introduced the mathematical aspects of paper-folding to Spain. **Back to Basics**: In general, an origami folder begins with a single uncut square piece of paper that can be creased. Origami paper (kami) comes in various sizes; most standard sizes are 3-inch, 6-inch and 10-inch squares and can be brought in most art & craft stores. Most origami products come with simple instructions and diagrams of basic folds like valley vs. mountain, pleats and reverse folds. There are also intermediate stages like bird base, fish base, water-bomb base, and frog base. The crane is one of the most recognizable origami designs partly popularized by the story of Sadako Sasaki (佐々木 禎子, January 7, 1943 – October 25, 1955) and the folding of a 1000 cranes. Origami representations include animate objects (example: a crane), inanimate objects (example: a camera), and abstract objects (example: a polyhedron).

Modern Origami Inspires Cutting-Edge Technology and Design: Today the word "origami" is used to include all types of folding, regardless of country of origin. As an artist, I'm thrilled when art and culture transform science and math. What I find intriguing is how advanced technology and modern math theories have recently made the "odd pairing" of origami and engineering a reality with real life applications. Scientists have developed a self-folding technology called aeroMorph. NASA is designing foldable solar arrays in a single rocket launch to harvest solar power to be wirelessly transmitted back to Earth. Origami is revolutionizing medical procedures to become less costly, less invasive and more efficient. Classic origami chompers have been turned into miniature forceps resulting in the design of super small surgical robotic tools. Here the traditional art form of origami is informing advanced engineering. What an exciting phenomena!

Origami artists are pushing origami to the extreme. There are computer programs like TreeMakers and Origamizer that have cracked the code with algorithms that could determine how to fold a piece of paper into any conceivable 3-D shapes. Scientists at the University of Twente in the Netherlands have created flat objects that morph into shapes that open and close like a blossoming flower after a drop of water. This is a cross between 4-D printing (self-assembling objects) and the craft of origami.

In Spring 2018, I took a seminar titled "Origami Engineering" with University of Pennsylvania Professor Cynthia Sung. This seminar broadens my knowledge of origami with topics such as kirigami, flat folding of maps, letterlocking, "fold and one cut", tessellations and auxetics, treemaker vs. origamizer, modular origami, polyhedron folding, kinetic (action) origami, foldable and responsive soft meta-materials. I find it necessary to gather a partial list of modern origami experts. Please note: After each description, there is a website or a video link for additional information.

A Partial List of Modern Origami Experts with Websites or Video Links:

Cynthia Sung (USA): Professor, Dept. of Mechanical Engineering and Applied Mechanics (MEAM), University of Pennsylvania. Member of General Robotics, Automation, Sensing & Perception (GRASP) Lab. Research on the intersection of computational geometry and fabrication using techniques such as 3D printing and origami-inspired assembly for robotic designs. http://www.seas.upenn.edu/~crsung/

Akira Yoshizawa (Japan)**:** is considered the grandmaster of origami, raising origami from a craft to an art form with his 1950 book of new modern models and diagrams. Pioneered the wet-fold technique. https://www.youtube.com/watch?v=GqH9eVdOI4M

David Baker (USA): a biology scientist, designing (lowest energy state) protein to aim to revolutionize medicines and materials. Computer game Foldit https://fold.it/portal/ http://www.sciencemag.org/news/2016/07/protein-designer-aims-revolutionize-medicines-and-materials

Jana Dambrogio (USA): a conservator, educator, & artist, MIT. Coined the term *letterlocking* in 2009 to describe the systems of deliberate folds, slits, flaps, locks, cuts, or seals that build security and privacy in letter delivery. http://www.janadambrogio.com

Erik Demaine (Canada/USA)**:** a MIT professor of Electrical Engineering and Computer Science who derived an algorithm and computational method to efficiently fold any specified shape from a sheet of paper. **Martin Demaine**: father of Erik Demaine, an artist and a mathematician who joint works with Eric focused on the math of folding and unfolding. Both father and son were featured in *Between the Folds*, a documentary on modern origami. Their work *Curved-Crease Sculpture* manipulate flat paper into swirling forms that "feel alive." http://erikdemaine.org

Peter Engel (USA): an influential origami artist and theorist, science writer, graphic designer and architect. Author of *Origami From Angelfish to Zen*.

Vincent Flodder (France): an artist, uses the concepts of crumpling, flexiables and inflatables to make installations and sculptures such as mushrooms. https://www.thirteen.org/programs/nova/nova-origami-revolution-episode/

Tomoko Fuse (Japan): famous for her modular origami, tessellation and gift boxes. https://www.youtube.com/watch?v=0g-y5825Xkk

Dinh Truong Giang (Vietnam): an origami sculptor of stylized figures of humans and animals inspired by Zen's art and philosophy. https://giangdinh.com

Miri Golan (Israel): Founded the 'Folding Together' project to bring together Israeli and Palestinian children from the Jerusalem area. http://www.foldingtogether.org/team.htm

Alma Haser (Germany)**:** a London-based photographer, uses folded-paper imagery in a portrait series titled Cosmetic Surgery. http://www.desotogallery.com/artists/alma-haser

Larry L. Howell (USA): engineer, professor (Brigham Young University), uses "thick origami", "flasher pattern", and hinges to design foldable materials from kevlar ballistic barrier to shield gunshots and solar array. https://me.byu.edu/faculty/larryhowell

Tom Hull (USA): a professor of mathematics, best-known for using origami to teach math with his book *Project Origami*. https://www.youtube.com/watch?v=aJ7OUaQEbOk

Paul Jackson (UK/Israel): a professional origami artist and author, uses techniques of folding such as pleated surfaces, curved folding and crumpling in his work. http://www.origami-artist.com/introduction.htm

Randall D. Kamien (USA): a professor (University of Pennsylvania). Research centers on the soft condensed matter theory. Developing simple methods to build kirigami 3D structures of soft materials from flat sheets. https://www.physics.upenn.edu/node/45464

Yves Klett (Germany): mechanical engineer, uses tessellation origami to design strong materials for aerospace in industrial scales. Folding machines for mass production. https://www.youtube.com/watch?v=Cb0CH60AIfM

Goran Konjevod (Croatia)**:** a mathematician and computer scientist, creates origami of abstract shapes formed from irregular patterns, his layered work relies on natural tension found in the paper. https://www.youtube.com/watch?v=yKPDwP9mHYk

Kaori Kuribayashi (Japan): Hobbkaio. Use origami techniques to design medicinal devices like stent graft. http://www.eng.ox.ac.uk/civil/publications/theses/kuribayashi

Robert J. Lang (USA): a former NASA physicist, currently an origami artist, uses math to create life-sized models. Collaborated w. scientists in designing airbags, medical devices, and telescope optics. https://www.youtube.com/watch?v=NYKcOFQCeno

Sipho Mabona (Switzerland/South Africa): an artist, created a full-scale *White Elephant* from one piece of paper and thought-provoking installations like *Swarm of Locusts* made out of dollar bills. https://www.youtube.com/watch?v=vYrQ2j0Z8h8

L. Mahadevan (USA): Harvard University. Uses math to understand the organization of matter in space and time, particularly at the scale observable by our unaided senses with ties to experiences and experiments. https://www.seas.harvard.edu/softmat/

Mademoiselle Maurice (France): a street artist who employs simple origami shapes in large quantities for unique public installations such as decorating the façade of a chapel. http://www.mademoisellemaurice.com

Jeannine Mosley (USA): best known for her origami made out of 66,000 business cards based on a fractal called Menger Sponge. https://openlearning.mit.edu/news-events/blog/mega-menger-building-menger-sponge-mit

Jo Nakashima: creates origami kinetic sculptures, reimagined the t-shirt w. movements and 3-D elements. https://www.youtube.com/channel/UC3ICcukYYeSn26KlCRnhOhA

Mark Neyrinck (USA): Astrophysicist, John Hopkins University, uses origami twist folds to understand the skeleton of dark matter in the cosmic. https://www.huffingtonpost.com/entry/the-cosmic-spiderweb-on-all-dark-matter-haloes-eve_us_59ecb449e4b092f9f2419314

Yuko Nishimura (Japan): creates large relief sculptures w. accordion folds using light and shadow. https://www.yellowtrace.com.au/yuko-nishimura-folded-paper-sculptures/

James Roper (UK): Manchester-based artist. Folded 10,000 origami flowers in an installation inspired by the Japanese tradition of folding 1,000 paper cranes in order to be granted a wish. http://jroper.co.uk/sculpture/origami/index.html

Richard Sweeney (UK): manipulates paper with cuts and folds to experiment and make unique forms of sculptures. https://www.youtube.com/watch?v=DoJqMeYSKsw

Jacqui Symons (UK): uses origami to create immersive installations with multiples and repetition. Works include a wave from 2,500 folded paper boxes and a suspending 5,000 origami fish to celebrate the Chinese New Year. http://www.jacquisymons.co.uk

Tomohiro Tachi (Japan): professor in Graphic and Computer Sciences at the University of Tokyo, developed origami software tools including "rigid origami simulator", "origamizer" and "freeform origami". https://www.youtube.com/watch?v=9i24C9r-NtE

Robert Wood (USA): Harvard. Uses "fold and cut" techniques of flat materials to design microrobots, the size of an insect. https://www.seas.harvard.edu/directory/rjwood

Joseph Wu (Canada): uses paper-folding to deal with his ADHD and depression. http://www.cbc.ca/arts/exhibitionists/origami-isn-t-a-kid-s-craft-joseph-wu-uses-the-paper-art-to-battle-depression-1.4599519

Shu Yang (China/USA): a professor and material scientist, University of Pennsylvania, relates origami and kirigami concepts to her research of synthesis, fabrication and assembly of polymers, liquid crystals and colloids to engineer innovative materials. http://www.seas.upenn.edu/~shuyang/

Glossary of Origami Terms

crease vs. fold: a crease is the line in the paper when you unfold a particular move; whereas a fold is a completed move. **There are two basic types of folds: valley folds and mountain folds.** In origami diagram, a dotted line means to fold the paper so it looks like the fold is a valley between two hills. The opposite of a **valley fold** is a **mountain fold**. The dotted and dashed line means to fold the paper so it looks like a mountain.

flap: a region of paper in an origami shape that is attached only along one edge so that it can be easily manipulated by itself.

hinge: a joint between two flaps.

kinetic (action): origami that moves or uses the kinetic energy of a person's hands, applied at a certain region on the model, to move another flap or limb. Ex: flapping bird, jumping frog.

kirigami: uses bending, folding, cutting and pasting to create complex 3D structure from a flat sheet.

locking: a move that helps to hold in shape, often the insertion of a flap into a pocket.

model: a three-dimensional representation of a person or object, typically in a smaller version than the original. A folded crane represents the bird.

modular origami: a technique to use multiple (Sonobe) units that are easy to fold to combine into more complicated forms such as a tetrahedron (≥3 Sonobe units), cube (≥6 units), octahedron (≥12 units), icosahedron (≥30 units) and buckyball (≥60 units).

point/vertex: the intersection of creases or folds. The corners of the paper and the free ends of flaps may also be referred to as points.

pleat fold : a fold formed by two parallel or nearly parallel mountain folds and valley folds formed through all layers of a flap.

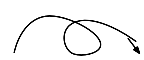
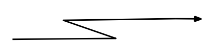
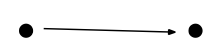
snapology: a type of unit origami created by Heinz Strobl which requires the folding of strips of paper to produce complex origami pieces.

tessellation: In Math, a collection of figures filling a plane with no gaps or overlaps. In origami tessellations, pleats are used to connect molecules such as twist folds together in a repeating fashion.

three-step model : a universal description of the general folding sequence for a model designed by technical folding. The three steps are: precreasing, collapse and shaping.

tree theory: the body of knowledge that describes the quantitative construction of crease patterns for uniaxial bases based on a correspondence between features of a tree graph and features in the crease pattern.

Folding Symbols Key

Valley Fold	_ _ _ _ _ _ _ _ _ _ _ _ _ _
Mountain Fold	_ · _ · _ · _ · _ · _ · _ · _ · _
Guidelines	………………………………..
Crease Line	______________________
Fold This Way	
Fold Behind	
Fold then Unfold	
Turn Over	
Pleat Fold	
Fold from one dot	

https://favemom.com/basic-origami-folding-symbols/

Newton's Three Laws of Motion

While students may know what Newton's laws say, many do not understand or simply do not believe what these laws mean. Misconceptions of these basic laws hinder future learning of physics. Origami can be used to help students to unlearn these misconceptions.

Brief descriptions of Newton's Three Laws of Motion:

- **1st Law:** Every object continues in its state of rest or of uniform motion, unless, acted on by a force applied from the outside. Therefore, both situations (objects at rest and object in motion) have the tendency to remain as balanced forces.

- **2nd Law:** Change of motion is proportional to the applied force and takes place in the direction in which the force acts. The equation F = ma illustrating that unbalanced forces has an acceleration that depends directly on the net force applied to the object, and depends inversely on object's mass.

- **3rd Law:** For every action, there is an equal and opposite reaction. Therefore, forces always come in pairs like two pears. For example, when your foot pushing on the ground (ACTION), an equal and opposite force (REACTION) of the ground is pushing on your foot. Another common example is the Newton's Cradle with pendulum balls.

Brief Biography of Sir Isaac Newton

Famous Quotes of Newton: *We build too many walls and not enough bridges.*
I can calculate the motion of heavenly bodies, but not the madness of people.
If I have seen further than others, it is by standing upon the shoulders of Giants.

Sir Isaac Newton (1643-1727) was an English physicist, astronomer, mathematician, philosophers and author. He is still considered by many as one of the most influential scientists of all time, and a key figure in modern scientific revolution.

Besides his work on gravity, Newton developed the three laws of motion (the basic principles of modern physics). His discovery of calculus led the way to more powerful methods of solving math problems. His work in optics included the study of white light and the discovery of the color spectrum. Many of Newton's experiments and discoveries were accomplished at a young age, but most were documented only in his notebooks. It was not until he was 42 years of age that he began writing and published his first book, *Principia Mathematica Philosophiae Naturalis* (Mathematical Principles of Natural Philosophy) which is often accepted as the greatest scientific book ever written.

Newton was a man of great ego, arrogance and temper. He had few close friends. His dispute with German mathematician Gottfried Leibniz over the invention of calculus is legendary. Fellow scientists like John Flamsteed, Robert

Hooke, and Henry Oldenberg were also his rivals. In February 1676 Newton wrote to Hooke "if I have seen further it is by standing on the shoulders of Giants." This famous quote was intended as an insult to Hooke, who was hunchbacked and may have suffered dwarfism, and definitely not a sign of Newton's great humility.

Unlike many intellectuals of his times, Newton was good with his hands. He could work with metal, wood and glass to construct things like his own telescopes. In his old age, Newton confided to his friend John Conduitt that he made his own tools because "if I had stayed for other people to make my tools and things for me, I would have never made anything of [my theories]."

Glossary for Force and Motion

acceleration: the rate at which velocity changes over time; an object accelerates if its speed, direction, or both change

balanced forces: two forces acting on an object in opposite directions and of equal sizes. **unbalanced forces** cause an object to move, stop, change speed, or change direction.

center of gravity: an imaginary point in a body of matter where the total mass of the body may be thought to be concentrated. The concept is sometimes useful in designing static structures (e.g., buildings and bridges) or in predicting the behavior of a moving body when it is acted on by gravity.

force: a push or pull exerted on an object in order to change the motion of the object; force has size and direction. **net force**: combination of all forces acting on an object

free fall: the motion of an object when only the force of gravity is acting on it

friction: a force that opposes motion between two surfaces that are in contact

gravity: a force of attraction between objects that is due to their masses

inertia: the tendency of an object to resist being moved or, if the object is moving, to resist a change in speed or direction until an outside force acts on the object

motion: an object's change in position relative to a reference point

mass: a measure of the amount of matter/inertial property in an object. **weight:** a measure of the gravity on an object, or the force needed to support it. The pull of gravity on the earth gives an object a downward acceleration of about 9.8 m/s^2.

projectile motion: the curved path that an object follows when thrown, launched, or otherwise projected

speed: the distance traveled divided by the time it took to travel
velocity: the speed of an object in a particular direction

Overall Unit Schedule

This curriculum unit consists of a sequence of Science, Math, ELA and Art lessons that can fit into a 10 weeks timeframe. There are 3 major components: 1) Individual Challenges and Introduction; 2) Science Lessons on Newton's Three Laws of Motion; 3) Class Challenges with Modular Origami. For weeks 7, 8, and 9, teachers will schedule individual conferences to guide students to complete the Egg Container Project and the Superhero Project. During the last week (Week 10), students will present these two individual projects. As a culminating event celebration, parents will be invite for the design display and the hallway bulletin board will be set up with students' work during the report card parent conferences. Viewing of a Superhero movie (Ex: The Incredibles, 2004) will serve as a class reward.

Project Challenges and Introduction to:

- Science Unit 1 Topic of Force and Motion,
- Origami Boxes (Egg Paper-Container Project)
- "Fold and One Cut" Technique (Superhero Letter Emblem)

Project 1 Introductory Lesson: Demonstration of a Simple Origami (Open) Box To jumpstart the design for a Egg Paper-Container. Due mid-October.

Project 2 Introductory Lesson: Origami Letter Emblem for Superhero Project. Due end of Oct., before Halloween.

Science Lessons:

Lesson 1: Netwon's 1st Law of Motion (Law of Inertia)

Lesson 2: Netwon's 2nd Law (Law of Gravity, F=ma):

Lesson 3: Netwon's 3rd Law (Action & Reaction):

Lesson 4: Class Challenge w. Modular or Non-modular Origami

Unit Assessments:

- **Question & Answers about Newton's Three Laws of Motion** (Appendix A5.1)
- **Individual Conferences** (Appendix A5.2) Set student's individual goals
- **Project Oral Presentations** (Appendix A6)

Teaching Strategies:

The teaching strategies for the Egg Paper Container Project and the Superhero (Letters) Project can be categorized as STEM inquiry and research-based learning. For the 4 science lessons on Force and Motion, students will conduct experiments with hand-on discoveries as they explore and discuss Newton's Three Laws of Motion. Close reading of scientific information with graphic organizers will be helped students to understand abstract concepts as they read and write. Individual conferences will be scheduled throughout the unit to check understanding and assess progress. Students will write their oral presentations of the two projects, and practice public speaking to obtain mastery before the final week. In general, each lesson will start with an opening activity to activate prior knowledge of key concepts. Teachers will use cues, pauses, and critical questions to facilitate discussions. Four distinct lists of academic vocabulary written on anchor charts will be posted: 1) science; 2) origami; 3) math; 4) Greek and Latin prefixes, roots and suffixes. Students will record vocabulary words, findings and reflections in their notebooks for future references. **Learning to how to fold:** Teachers will give demonstrations with direct instruction as well as show tutorial videos. Videos will be available on Google Classroom. Since each origami is a non-linguistic representation, it is important to allow students sufficient time and space as well as multiple opportunities to master each design. Cooperative learning, peer teaching, flexible groupings and learning centers will be crucial to help with time and classroom management.

Lastly, mastery learning is used as a high impact strategy where teachers will teach the needed knowledge explicitly up front, allow students to practice folding, and then have students to revisit the folding patterns repeatedly until the knowledge is internalized. Performance tasks and formative assessments such as exit tickets will be given when appropriate to further instruction.

General Science Process and Skills Addressed:

Observe, Inquire, Compare & Contrast, Describe, Experiment, Identify Patterns, Predict, Construct/Create, Measure, Apply, Communicate/Cooperate, Problem-Solve, Spatial Reasoning, Make Conclusions.

Mathematical Eight Standard Practices Addressed:

1. Make sense of problems and persevere in solving them.
2. Reason abstractly and quantitatively.
3. Construct viable arguments and critique the reasoning of others.
4. Model with mathematics
5. Use appropriate tools strategically.
6. Attend to precision.
7. Look for and make use of structure.
8. Look for and express regularity in repeated reasoning

Classroom Activities, Resources and Appendices

Project 1 Introductory Lesson:

Demonstration of a Simple Origami (Open) Box
to Introduce Project Assignment to Design a Paper Container for an Egg.

Learning Outcomes: SWBAT replicate a basic origami box following the teacher's instructions and demonstration IOT jumpstart project ideas to create a container made out of paper to protect an uncooked egg from the impact of a nine-feet drop.

Evidence of Learning: Precision of the box with straight lines & 90 degrees angles.
*For details about project assignment and rubric, See *Appendix P.1.1 and Appendix P.1.2*

Math Key Concepts and Content: volume, V=lwh, length, width, height, cube, rectangular prism, right angle and symbol ∟ 90°, symmetry of a square.
Math Common Core Standards: Use equivalent fractions: **5.NF.A.1.**
Concepts of volume: **5.MD.C.3, 5.MD.C.4, 5.MD.C.5**. **Math Practice Standards: #1** Make Sense and Persevere, **#4** Model with mathematics, **#5** Use appropriate tools strategically, **#6** Attend to precision.

Pre-requisite 1: **Connection to students' knowledge, skills and experience by** quickly assess students' dexterity, understanding of symmetry and exponential growth w. this challenge: **How many times can you fold a piece of paper in half?**
Myth: You can't fold a paper in half more than **8 times**.
Reality: Given a paper large enough with enough force, you can fold it in half infinitely.
Problem: If you fold the paper **103 times**, its thickness will be greater than the Universe, i.e. 93 billion light-years. For more detailed explanations, see website and video link https://sploid.gizmodo.com/if-you-fold-a-paper-in-half-103-times-it-will-be-as-thi-1607632639

Pre-requisite 2: Review origami vocabulary words and symbols with students. http://creased.com/baseics/pdf/baseics.pdf **Advice**: Teachers should practice the steps of folding a simple box before lesson, but don't be afraid to make mistakes while teaching. Remember to learn with your students. Don't underestimate your student abilities. From my own experience, I had Learning Support and ESOL students who led their peers immediately after my demonstration or after viewing tutorial videos on their own.

Teaching Strategies and Sequences
1. Opening (15 minutes)

- Explain to students that there are many different versions of origami boxes they can make out of just one piece of paper or with (easy to make) modular units (three or more pieces of paper).
- Visually show the following origami boxes: square, hinged, hexagonal, octagonal, rose, etc. There are endless varieties online. The following photos are cubes, rectangular prisms and tetrahedrons that my former 5th graders (FY 2017-2018)

had made for a service-learning project on “Kids Home Alone” in collaboration with a Philadelphia-based organization Need in Deed.

2. Instruction (30 minutes):

- Teacher demonstrates how to fold a simple **open** origami box with a square paper (6” x 6” or 8” x 8”) using step-by-step photos http://www.origami-instructions.com/origami-box.html or show the following YouTube video https://www.youtube.com/watch?v=_CkHEk2NqtY
- If it is helpful, distribute written instructions w. diagrams for students. **See Appendix P.1.3 or visit** https://found-here.info/how-to-do-an-origami-box/how-to-do-an-origami-box-how-to-make-easy-origami-box-box-1-easy-origami-instructions-for-templates/

3. Guided Practice (30 minutes):

- Make available square papers of different sizes (such a 3 ½”, 4 ⅔”, 5¾”, 6⅛”) to encourage students to use rulers as a measuring tool.
- Teacher walks around to offer assistance and feedback as students fold a second origami box with peer assistance. Insist on precision of lines and 90-degree angles. Explain a crease should resolved; it is exactly where you intended it to be, it is sharp and straight, without any bubbles, and not wavy.

4. Independent Practice (Time varies):

- For most students, it may take 2 to 3 trials to make a box with precise measurements. Give students time and space within a week to practice.

5. Extended Practice for Mastery Learning (Time varies):

- With additional assignments for homework and Math Centers, teachers will be able to create multiple opportunities for students to develop their muscle memory to be able to fold the box with less and less support, less and less instruction and use more and more of their own intuition.
- Challenge students to make a **closed** gift box. Examples: 1) use the open boxes as top and bottom, 2) hinged box https://www.youtube.com/watch?v=rs35JsoJlFQ, 3) rectangular prism; 4) tetrahedrons.

- **For students who *struggle* with this learning, they will** practice how to fold and make creases with more precision and practice for easier origami models like a sailboat (only 2 folds, https://www.youtube.com/watch?v=NcieP3uy4Dc). I will also partner struggling students with helpers.
- **For students who *master* this learning quickly, they will** mentor other students, lead small groups, and challenge them to make more complex models like a junk (https://www.youtube.com/watch?v=jWlVHrTvqes)

Materials and Resources:

- Pre-cut copy paper squares with the dimensions of 6" x 6" or 8" x 8"
- **Online**: you can purchase Hamburger Patty Paper (pack of 1,000, 5.5" x 5.5"), **Brands:** Papercon, 1000 sheets P6L 6x6
  UltraSource 192033, PaperWax, 1000 sheet 5 ½" x 5 ½"
- Rulers in centimeters and inches
- Copies of written instructions

Additional Videos for beginners:

- https://www.youtube.com/watch?v=UhjDar0YdAo, "20 in 1 Origami (20 Origami models from one paper) - Tutorial from Paper Folds", January 8, 2017. https://www.youtube.com/channel/UCaoR_1kKoIDBAuCw67W_oHg

****

Project 2 Introductory Lesson:
Origami Letter Emblem for Superheroes (due end of Oct. around Halloween).

Learning Outcomes: SWBAT make a mask and/or cape with letter emblem from their selected Greek and Latin prefix, root and/or suffix to visually create a representation of an unique superhero IOT build a richer vocabulary. SWBAT write a character monologue of a superhero IOT to develop the ability to construct narratives using Greek and Latin prefixes, roots and suffixes.

Evidence of Learning (product of assessment): Appendix P2.1 and P.2.2
ELA Key Concepts and Content: Latin and Greek prefixes, roots and suffixes. See Appendix P. 2.3. **ELA Common Core Standards:** RI.5.4

Teaching Strategies and Sequences:
1. Opening (15 minutes):

- Read and study the poem Jabberwocky by Lewis Carroll from http://www.alice-in-wonderland.net/resources/analysis/poem-origins/jabberwocky/
- Listen to poem reading by celebrities https://www.emtwytte.com/2016/03/25/5-celebrities-reading-lewis-carrolls-jabberwocky/
- Discuss the term "portmanteaus", a word that is made up of other words. Example: podcast is a portmanteau, a made-up word coined from a combination of the words iPod and broadcast"
- Discuss what are prefixes, roots and suffixes.

2. Instruction (30 minutes):

Superhero Project Requirement: Use either Erik Demaine's "Fold and One Cut" technique or Jo Nakashima's folding technique to make an origami-inspired letter emblem for your superhero costume.

- Demonstrate how to use the "fold and one cut" technique to cut a letter A. Use **Appendix P.2.4:** Template for Letter A or visit http://erikdemaine.org/fonts/simplefoldcut/
- Show video of Jo Nakashima's creation of the Letter A https://www.youtube.com/watch?v=rkT6dKXuIr8&list=PL0FAA790A9E1EFEFB
- Provide students with a list of Latin and Greek prefixes, roots and suffixes as well as video links to research their own choice of prefixes, roots and suffixes. **Appendix P.2.3:** List of 30 Prefixes, 39 Roots and 24 Suffixes
- Teacher will pick a root to demonstrate how to construct a real or nonsense word. Ex: bio-dyna-ship https://www.mpc.edu/home/showdocument?id=12804

3. Guided Practice (30 minutes)

- Help students choose a root that they are happy with. Encourage each student to master a different prefix, root and suffix from the list to be able to teach and share the knowledge with other students throughout the year. Offer suggestions in terms of color, text font, shape for their letter emblem.

4. Independent Practice (Time varies):

- Students will construct their letter emblems and other parts of their superhero costume during daily (ELA or Math) center time (30 minutes) and at home.

5. Extended Practice for Mastery Learning (Time varies):

- Students will write a monologue of their superheroes with backstory, etc. using Google Doc and/or PowerPoint to put learned words in contexts of a narrative.
- For students who struggle with this learning, they will make just one letter.
- For students who master this learning quickly, challenge them to "fold and one cut" a series of letters such as "BIO", "GEO", etc.

Materials and Resources:

- Recyclable Paper of various sizes and thickness
- Recyclable T-shirts or other fabrics, needles and threads.
- Scissors, rulers and measuring tapes
- Copy of the poem "Jabberwocky"
- **Appendix P.2.1:** Superhero Assignment
- **Appendix P.2.2:** Superhero Grading Sheet/Rubric
- **Appendix P.2.3:** List of Prefixes, Roots and Suffixes
- **Appendix P.2.4:** Template for Letter A "Fold and One Cut" Technique

Lesson 1: Netwon's 1st Law of Motion (Law of Inertia)

Learning Outcomes:

- SWBAT perform "push and pull" experiment(s) IOT investigate Newton's 1st Law of Motion and understand why objects at rest, stay at rest verse why objects in motion, stay in motion.

Evidence of Learning (product of assessment): Complete **Appendix L1** to record observations, discussion and questions during classwork and/or homework.
Select a question about the 1st Law from **Appendix L5.1** as an exit ticket.

Key Concepts and Content: force, motion, push and pull, inertia, balanced and unbalanced forces, center of gravity.

Pre-requisite: Connection to Students' knowledge, skills and experience
Students should refer to their understanding of force and motion from previous lessons and be written the **1st Law in their notebook:** "Every object continues in its state of rest or of uniform motion, unless, acted on by a force applied from the outside."

Teaching Sequence and Strategies:

1. Opening (15 min):

- Ask for 2 volunteers. One student sits on a chair with wheels. Another on a chair w/o wheels. Teacher or a student will push each chair to make it moves. Optional: Repeat the process by pulling.
- Students will "Think, Pair, Write and Share" to articulate why it took less force to move the student who is sitting on a chair with wheels than without wheels.
- **Teacher:** Record predictions, reasons, and vocabulary words on chart paper
- **Student:** Discuss in groups of 3 to 6. Record key concepts/words in notebook.

2. Instruction (15 minutes)

- Discuss the differences between balanced and unbalanced forces.
- Show the following videos
  1) Balancing eagle. https://www.youtube.com/watch?v=uptSbW0Cwl8
  2) Hangers & tennis balls. https://www.youtube.com/watch?v=fi-jMVb8WJs
- If desired, the cost of a 7-inch balancing eagle range from $3 to $7 and can be purchased online. Or challenge students to make models of a balancing eagle and hangers w. tennis balls for extra credits.
  https://www.youtube.com/watch?v=yRN-AWenFqc (origami dollar bill eagle)
  https://www.youtube.com/watch?v=3q7THJUSKto (styrofoam plate eagle)
  http://www.physicsclassroom.com/class/newtlaws/Lesson-1/Newton-s-First-Law
- **Teacher:** Write key words on board. Select and prepare to show videos.
- **Student:** Write key words, observation and discussion in notebook.

3. Experiment with Guided Practice (30 minutes)

Define **inertia** and **center of gravity** with the following experiments
Show video(s) to model how experiment(s) of choice.

Inertia (objects at rest, stay at rest)

- Experiment 1: Coin Drop https://www.youtube.com/watch?v=qq1Whusk8No
- Experiment 2: Stack of Coins https://www.youtube.com/watch?v=1hPJ0vQpFts
- Experiment 3: Egg Drop https://www.stevespanglerscience.com/lab/experiments/egg-drop-inertia-trick/

Inertia (objects in motion, stay in motion)

- Define **friction**, **momentum**, **kinetic energy** and **potential energy**.
- Experiment 1: Coins Spin inside a Balloon https://www.stevespanglerscience.com/lab/experiments/spinning-penny/
- Experiment 2: Rolling Balls https://www.youtube.com/watch?v=_8YW2reAQtM
- Experiment 3: Stacked Balls Drop https://www.sciencealert.com/watch-here-s-why-the-stacked-ball-drop-experiment-is-like-a-supernova

Center of Gravity

- Experiment 1: Soda can http://www.indypl.org/kids/blog/?p=8933
- Experiment 2: Yardstick https://www.exploratorium.edu/snacks/center-gravity
- Experiment 3: Two Forks https://www.youtube.com/watch?v=BMwAYJNgIwc
  Experiment 4: Balancing Regular & Irregular Shapes https://www.youtube.com/watch?v=YN2oALaRfL4

Student will work in pairs or in groups of 3-4 using **Appendix L1** to record observations, discussion and questions during classwork and/or homework. **Teacher will circulate to** give immediate feedbacks and support.

4. Independent Practice and Homework

- Repeat experiments if necessary, and complete **Appendix L1** during Centers (30 minutes daily) and/or as homework

5. Extended Practice for Mastery Learning

- Connect their understanding to research for more information and examples of Newton's Three Laws of Motion.
- **For students who struggle with this learning, they will** play a balancing game like Melissa & Doug Suspend Family Game (List Price: $16.99)
- **For students who master this learning quickly, they will** design a controlled balancing experiment or game with independent and dependent variables to explain the 1st Law. Students plot their data with x and y-axis to make line graphs for data analysis, conclusion and further research.

Materials and Resources:

- Review selected experiment video for the listing of materials
- **Appendix L1**
- Store brought games (Jenga, Tip It, etc.) or self-made balancing games (balancing playing cards, chopsticks on cups, stacking coins, etc.)

Lesson 2: Netwon's 2nd Law (Law of Gravity, F=ma):

Learning Outcomes:

- SWBAT observe and record the falling speed of a crumpled paper ball and other objects IOT explain why all objects fall at the same rate regardless of their mass and answer questions about the motion of objects as it relates to its mass.
- SWBAT to compare how the number of mountain folds and the number of valley folds do not alter the acceleration of a falling paper of the same mass IOT understand the force acting on the paper is equal to mass of the paper times the acceleration of the paper (Newton's second law of motion).

Evidence of Learning (product of assessment): Complete **Appendix L2** to record observations, discussion and questions during classwork and/or homework.
Select a question about the 2nd Law from **Appendix L5.1** as an exit ticket.

Key Concepts and Content: mass, weight, gravity, air resistance, acceleration of free falling objects, gravity, Newton's second law of motion (F=ma).

Pre-requisite: Connect students' knowledge, skills and experience with a brief recap of previous lessons about Newton's three laws.

Background: Introduce **2nd Law** with "the change of motion is proportional to the applied force and takes place in the direction in which the force acts. F=ma." The second law pertains to the behavior of objects for which all existing forces are **<u>not</u> balanced** and it states that the **acceleration** of an object is dependent upon two variables: the **<u>net force</u>** acting upon the object and the **mass** of the object. The acceleration of an object depends directly upon the net force acting upon the object, and inversely upon the mass of the object. In other words, as the force acting upon an object is increased, the acceleration of the object is increased; As the mass of an object is increased, the acceleration of the object is decreased.

Teaching Sequence and Strategies:
1. Opening (15 min):

- Ask students to predict which one of the following objects: a paper ball or a cotton ball would fall fastest and hit the ground first. Make sure to the crumpled paper ball is about the same size and shape as the cotton ball.
- **Teacher:** Record predictions, reasons, time in seconds of each falling objects
- **Student:** Discuss in groups of 3 to 6 to make a hypothesis.

2. Instruction (30 minutes) Refer to Science Glossary for definitions.

- Discuss the differences between mass and weight. Write key words on board.
- Use a scale to weigh the paper ball and the cotton ball to show differences in mass
- Identify the different mass/weight as the independent variables (y-axis). The similar sphere shape and size of both balls are the controlled variables. The time in seconds of each fall is the dependent variables (x-axis).

- After recording prediction and hypothesis on chart paper, drop the paper and cotton balls simultaneously 3 meters (≈ 9 to 10 feet) from the ground. Be careful if you are standing on a table or using a ladder for the drop. If possible, record the number of seconds with two to three separate timers, and then have students calculate the average.
- In Notebooks, students write key words, record time in seconds and observation, and answer the question **"Why all free falling object fall at the same rate regardless of mass?" Background: <u>All objects fall at the same rate</u>**. Objects dropped together from the same height will hit the ground at the same time. Free-falling objects accelerate by the force of gravity. On Earth, the acceleration due to gravity is approximately 9.8 m/s^2. Newton's 2^{nd} Law is $F = ma$, but since free falling objects are accelerated by gravity, Newton's 2^{nd} Law becomes $F = mg$.

3. Experiment for Guided Practice (30 minutes)

- **Experiment 1: Falling Objects**
  Distribute the ziplock bags of objects with different sizes, materials and shapes to students. Distribute a recording sheet with instruction to record distance fallen (meters) and time (seconds) with three trials for each falling object. Limit the height of the drop from the top of a desk for safety. Encourage students to explain verbally or in written form why objects fall at the same rate regardless of its mass. Students will record the distance fallen in meters and time in seconds. Students will graph the collected data with the x-axis labeled as time in seconds (dependent variable) and y-axis labeled as distance fallen in meters (independent variable). https://www.youtube.com/watch?v=xzA6IBWUEDE

- **Experiment 2: Acceleration Experiment: Mountain vs. Valley Folds**
  Drop 2 paper cups of the same size from the same distance with one cup is **faced down** and one cup is **faced up**. Write the formula F=ma (Newton's Second Law). Ask students to confirm in a vacuum (eliminate air resistance) the objects of different masses will fall at the same rate (acceleration/gravitational force of 9.8 m/s^2). **Questions:** Why a mountain fold falls differently or similarly to a flat piece of paper and a crumpled paper? What happen as the paper tips to one side? Would adding an extra fold makes it fall differently? How? Why? What do you think is happening as it falls? http://www.amedeo-itn.eu/uploads/files/AMEDEO_FallingWithStyle_Worksheet.pdf

- **Experiment 3**: Paper air resistance https://www.youtube.com/watch?v=O-KYLXp2MG4

- **Experiment 4**: Paper Tower https://www.youtube.com/watch?v=UeB5XhQ2FL4 https://www.youtube.com/watch?v=MMoHRaVSWnY

- **Experiment 5:** 5 Easy Science Experiments With Paper (Blossoming Flower) https://www.youtube.com/watch?v=HgCPaZ4d2ok

4. Independent Practice and Homework

- Ask students to identify an independent variable (example: paper balls of three different mass) to conduct their own controlled experiment.
- Perform 3 trials to calculate the average (m/s) for each independent variable.
- Students work in pairs to conduct another controlled experiment and answer questions independently for homework.

5. Extended Practice for Mastery Learning

- Connect their understanding to research for more information and examples of Newton's Three Laws of Motion. See additional videos below.
- Relate data to theories with line graphs (x-axis for the independent variables and y-axis for the dependent variables.)
- **For students who struggle with this learning, they will** identify the independent variables (ex.: 2 different sizes) and observe which size hits the ground faster.
- **For students who master this learning quickly, they will…** design an experiment with multiple independent variables (examples: three different sizes with three different materials would change the number of independent variables from 3 to 9). On a line graph, students will need to plot three separate lines.

Materials and Resources:

- In ziplock bags, prepare objects of different weights, shapes and sizes. Objects may include: paper of different sizes & weight, cotton balls, golf balls, tennis balls, paper clips, coins, etc.
- Timers, yardsticks or measuring tapes, scales to measure mass of objects
- Glossary of terms
- Appendix L2.1, L2.2 sheet and questions

****

Lesson 3: 3rd Law (Action & Reaction)

Learning Outcomes:

- SWBAT to use a kinetic origami IOT understand the force acting on the paper has an equal and oppositive force reacting to the applied force, i.e. Newton's 3rd law.

Evidence of Learning (product of assessment): Complete **Appendix L3** to record observations, discussion and questions during classwork and/or homework.
Select a question about the 3rd Law from **Appendix L5.1** as an exit ticket.

Key Concepts and Content: action, reaction, kinetic, potential energy, momentum, inertia (air resistance), **4 types of friction**: static, sliding, rolling, and fluid.

Pre-requisite: Connect students' knowledge, skills and experience with a brief recap of Newton's three laws. **3rd Law:** For every action, there is an equal & opposite reaction.

Teaching Strategies and Sequences:

1. **Opening:**

- Have a student to blow up a balloon but don't let go. Ask the class to make predictions as to what will happen if the student let go of the balloon? Write prediction and reasoning on chart paper.
- Have student let go of the balloon. "Think, Pair and Share" to discuss when happen to the balloon and why. Write observations in notebooks.

2. **Instruction (30 minutes):**
   - As a class watch the video "Science Experiments-Newton's 3rd law examples with Bruce Yeany" https://www.youtube.com/watch?v=fzFG2TPlrv8
   - Distribute **Appendix L3.2:** Third Law: Identify Action and Reaction. Explain and discuss #1 and #2 to assess understanding.

3. **Guided Practice (30 minutes)**
   - Allow time for students to work in groups to complete **Appendix L3.2**

Demo.	**Experiment**	**Action**	**Reaction**
#1	Scale	A person standing (pushing down) on the scale	The scale pushing up to the foot of the person
#2	Balloon	A person blows air into a balloon	When release, the air push out of the balloon
#3	Person Jumping on the Ground	A person's feet push down to the ground	The ground push up to the feet of the person
#4	Person Jumping on a Skateboard	A person's feet push down to the skateboard and the skateboard moves backwards	The skateboard pushes up to the feet of the person and the person stays at the same spot due to the action of the skateboard.
#5	Toy Car on Cardboard on Rolling Pencils	The wheels of the toy car pushes down on the cardboard. Cardboard pushes down on pencils.	Pencils roll backwards pushing up to the cardboard and the cardboard pushes up to the wheels of the car.
#6	Person pushes against a wall		
#7	Rocket Launch		
#8	A book rests on a table. Why the book is at the state of equilibrium? Equilibrium is a state in which opposing forces are balanced.		
#9	What happens to a person without a seatbelt during a car crash?		
#10	What happens to a person wearing a seatbelt during a car crash? Draw what happen on the space below.		

Guided Practices for Jumping Frog Experiment (another 30 min.)

- **Jumping Frog Experiment:** Demonstrate how to make a jumping frog. Watch videos or follow diagram instructions on **Appendix L.3.3**
  Note: Version 1 is easy. Version 2 is intermediate
  On Appendix L3.1, Students will record the following data:
  Distance jumped (meters), time (seconds), calculated speed (meters per seconds) https://www.youtube.com/watch?v=xzA6IBWUEDE

4. Independent Practice, Centers and Homework (Time Varies)

- Students will graph collected data with x-axis as time in seconds (dependent variable) and y-axis labeled as distance fallen in meters (independent variable). Students will make conclusions relating to the 3rd Law.

5. Extended Practice for Mastery Learning:

Students can conduct any of the followings during centers for further study:

- **Experiment 1:** Bouncing Ball. Momentum, potiential energy.
  https://www.youtube.com/watch?v=MyyVSZ9OqD4
  https://www.youtube.com/watch?v=2UHS883_P60
- **Experiment 2:** Slinky http://www.instructables.com/id/Origami-Slinky/
  http://www.instructables.com/id/Expandingcollapsing-origami-bracelet/
- For students who struggle with this learning, they can make a simple flying helicopter and use it for their experiment. https://curiodyssey.org/wp-content/uploads/2017/04/CuriOdyssey_PaperHelicopters.pdf

- For students who master this learning quickly, they can attempt
  1) an infinite rotating tetrahedron (flexagon origami)
     https://www.youtube.com/watch?v=db8PniE4PmQ
  2) an interactive origami by Jo Nakashima
     http://www.instructables.com/id/Interactive-Origami-Sculpture/

Materials and Resources:

- Review selected experiment video for the listing of materials
- **Appendix L3.1 to L3.5**
- **Video** https://www.youtube.com/watch?v=AFwbcWIUwLQ
  Demos., Prof. Miller

Lesson 4: Set Up a Class Challenge
Learning Outcomes: SWBAT work together to set a goal making (non-modular and modular) origami models IOT meet a real-life challenge.

Ideas & Tips to Set Up Origami Class Challenges

Purpose: Origami can be an effective strategy for community building in the goal to promote an equitable and healthy competitiveness in how we learn and teach each other to be successful. While folding in solitude can be calming and energy-focused, folding with other people in a social atmosphere can develop students' communication skills, connections to real people and situation and class cohesion. Origami is not the magic pill but if use properly, it can open many doors of positive learning for both students and teachers from all walks of life.

How to Set Up a Class Challenge with Origami?

- Identify the purpose and goal
  Example 1: Submit a class sculpture for a competition with the goal of making at least 500 modular units. **Example 2:** Calculate how many cubes (what dimensions) the class needs to fold in order to cover the Math bulletin board to class understanding of volume.

- Advocate Mastery Learning as you teacher students how to fold a non-modular origami (any origami using one pieces of paper) or a modular origami.

- Advantages of modular units for class challenge:
  modular units are easy to teach and make. The modular units can often be assembled into large models or installation, as long as you want like a sling or as massive as you want like a polyhedron connected into a hanging sculpture (see below). https://ramaharo.wordpress.com/tag/penultimate-modular-origami/

- Examples of origami with modular units: Visit http://gurmeet.net/origami/
  - Slinky (Jo Nakashima's Version)
  - Any polyhedron (tetrahedron, octahedrons, etc.)
  - Gift Boxes (hexagonal box, magic rose cube)

Math Calculation Challenges

- Example 1 (Average): 10 boxes per 10 people = 1 box per person
- Example 2 (Rate): 30 boxes in 30 minutes = 1 box per minute
- Example 3 (Ratio): 20 boxes per 11 people, 10 boxes per 11 people, 11 boxes per 11 people, etc. Compare the above ratio to define how many boxes each person made. Distinguish how a ratio is not the same as a fraction.
- Example 4 (Estimation): Estimate the number of cubes (same or different sizes) that can be hold by a bin.
- Example 5 (Volume): Calculate the volume of a 2"x2"x2" cube and the volume of the bin (12"x 6"x 3"). Figure out how many cubes can the bin holds.

5. National Curriculum Standards and Overall Science, Math and ELA Objectives

Science Next Generation Science Standards: **3-PS2-1, 3-PS2-2**
Math Common Core Standards: **Fraction-5.NF.A.1. Volume-5.MD.C.3, C.4 and C.5**
ELA Common Core Standards: **RI.5.4**

This curriculum unit is based on the School District of Philadelphia (SDP) Science Unit 1 **Topic: Forces and Motion for 5th Grade**. Duration: 9-10 Weeks (Sept. to Nov., 2018) **Essential Questions:** How do balanced and unbalanced forces affect the motion of an object? How can the laws of motion help you predict future motion of an object?

Science Objectives: (Force and Motion)

1) SWBAT measure and record the speed of different paper-folding designs with (testable) independent variables IOT explain how an object's motion is related to force, mass, acceleration, gravity, air resistance, friction and inertia. 2) SWBAT identify patterns of motion based on data analysis IOT predict an object's future motion with evidences and understanding of the 3 Laws of Newton.

Next Generation Science Standards: **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. **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.

Math Objectives/Connections: (Fractions, Area Models, Volumes)

3) SWBAT perform operations with fractions and mixed numbers by using paper-folding models to explain calculations and equations IOT apply and extend their understanding of fractions with problems relating to forces and motions.

Math Common Core Standards: Use Equivalent Fractions to add and subtract fractions. 5.NF.A.1.Add and subtract fractions with unlike denominators (including mixed numbers) by replacing given fractions with equivalent fractions in such a way as to produce an equivalent sum or difference of fractions with like denominators. **Geometric Measurement: Concepts of Volume. 5.MD.C.3** Recognize volume as an attribute of solid figures and understand concepts of measurement. **5.MD.C.4** Measure volumes by counting unit cubes, using cubic cm, cubic in, cubic ft, and improvised units. **5.MD.C.5** Relate volume to addition and multiplication to solve real world problems.

ELA Objectives and Connections: (Craft and Structure: Vocabulary)

4) SWBAT write an original description and construct an origami costume of a superhero character based on a combination of Latin & Greek prefixes, roots and suffixes) IOT determine the meaning of unfamiliar words for information relating to forces and motion. **ELA Common Core Standards (Reading Information): RI.5.4** Determine the meaning of general academic and domain-specific words and phrases in a text relevant to a grade 5 topic or subject area. **Rationale:** 97% of the words that students will encounter are made up of 30 prefixes, 30 roots, and 30 suffixes. 70% of these words can be defined using word parts and 30% can be defined using context clues. Determining the meaning of phrases is a critical skill with implications for all later grades and disciplines.

Science References (APA)

Arifin, Nurul Hayati. (March 6, 2013). *Chapter 2: Force and Motion. 1.1.1 Distance and Displacement* [Graphs and Blog]. Physics Is Fun. http://nurulhayatiarifin.blogspot.com/2013/03/chapter-2-force-and-motion.html

CuriOdyssey. n.d. *At-Home Science Experiment: Paper Helicopters.* (pdf file) https://curiodyssey.org/wp-content/uploads/2017/04/CuriOdyssey_PaperHelicopters.pdf

Farina, Dave. [Professor Dave Explains]. (Feb 16, 2017). *Newton's First Law of Motion: Mass and Inertia.* (Video). https://www.youtube.com/watch?v=xzA6IBWUEDE

Farina, Dave. [Professor Dave Explains]. (Feb 20, 2017). *Newton's Second Law of Motion: F=ma.* (Video). https://www.youtube.com/watch?v=xzA6IBWUEDE

Farina, Dave. [Professor Dave Explains]. (Feb 23, 2017). *Newton's Third Law of Motion: Action and Reaction.* (Video). https://www.youtube.com/watch?v=y61_VPKH2B4

Hewitt, Paul G. (2015). *Conceptual Physics*. San Francisco: Pearson Addison Wesley.

Lancelot, Paul and Jopson, Juliet. (n.d.) *Falling with style: air resistance versus gravity.* AMEDEO ITN, EU FP7 Grant no. 316394. Retrieved http://www.amedeo-itn.eu/uploads/files/AMEDEO_FallingWithStyle_Worksheet.pdf. June 24, 2018.

n.a. (n.d). *Newton's Law of Motion Questions*. [pdf file]. Retrieved from https://www.shakopee.k12.mn.us/cms/lib07/MN01909221/Centricity/Domain/293/Laws%20of%20Motion%20Questions%20KEY.pdf

n.a., (n.d.), *Newton's Law of Motion*. (pdf file, questions). https://www.sas.upenn.edu/~kennethp/nkdievid2.pdf https://www.cusd80.com/cms/lib/AZ01001175/Centricity/Domain/8456/Newtons%20Laws%20Worksheet%20KEY.pdf

n.a., n.d. *Physical Science: Newton's Laws Worksheets* (pfd Questions & Answers). https://www.nwasco.k12.or.us/cms/lib04/OR01001464/Centricity/Domain/97/Newton_s%20laws%20worksheet.pdf

Pascal, Janet B. (October 30, 2014). *Who Was Issac Newton?* New York: Penguin Group.

The Physics Classroom. (1996-2018). *Newton's First Law.* Retrieved from http://www.physicsclassroom.com/class/newtlaws/Lesson-1/Newton-s-First-Law

The Physics Classroom. (1996-2018). *Newton's Second Law*. Retrieved from http://www.physicsclassroom.com/class/newtlaws/Lesson-3/Newton-s-Second-Law

The Physics Classroom. (1996-2018). *Newton's Three Law*. Retrieved from http://www.physicsclassroom.com/class/newtlaws/Lesson-4/Newton-s-Third-Law

Westfall, Richard S. (March 24, 2018). *Sir Isaac Newton*. Encyclopaedia Britannica, Inc., Retrieved http://www.britannica.com/biography/Issac-Newton. June 24, 2018.

Won, Kevin. (February 27, 2015). *Regular & Irregular Shapes: Center of Gravity.* [Slide Presentation]. Prezi. https://prezi.com/8pdntoyp9sjr/regular-and-irregular-shapes/

Zimba, Jason. (April 28, 2009). *Force and Motion: An Illustrated Guide to Newton's Laws*. Baltimore, Maryland: The John Hopkins University Press.

Science Experiment Videos:

Bergman, Chris. (February 8, 2014). *Station 3: Newton's Laws of Motion Lab.* (Video Tutorial). https://www.youtube.com/watch?v=fi-jMVb8WJs

Cowern, Diana. [Physics Girl]. (January 20, 2015). Stacked Ball Drop. (Video). https://www.youtube.com/watch?v=2UHS883_P60

Crew, Bec. (March 12, 2015). WATCH: Here's Why The Staked Ball Drop Is Like a Supernova. (Video). https://www.sciencealert.com/watch-here-s-why-the-stacked-ball-drop-experiment-is-like-a-supernova

Lavin, George. [BBC Earth Lab} (July 31, 2013). Making Bridges Out of Paper?! Earth Lab. (Video). https://www.youtube.com/watch?v=MMoHRaVSWnY

Miller, John Thomas. [John Thomas Miller]. (September 4, 2013). From a Bouncing Ball Experiment. (Video). https://www.youtube.com/watch?v=MyyVSZ9OqD4

n.a. [5 minutes]. (July 9, 2017). 5 Easy Science Experiments With Paper (Blossoming Flower). (Video). https://www.youtube.com/watch?v=HgCPaZ4d2ok

n.a. [Black Virus]. (October 1, 2017). *How to make a balancing bird toy*. (Video Tutorial). https://www.youtube.com/watch?v=3q7THJUSKto

n.a., n.d. *Center of Gravity.* https://www.exploratorium.edu/snacks/center-gravity

n.a. [Coolsville]. (December 27, 2015). *6 Inertia Experiments.* (Video Tutorial). https://www.youtube.com/watch?v=1hPJ0vQpFts

n.a. [d'Art of Science]. (December 25, 2014). *Center of Gravity experiment.* (Two Forks) https://www.youtube.com/watch?v=BMwAYJNgIwc

n.a. [ESTLA NASD]. (January 30, 2016). Rolling Ball Experiment-Law of Motion. (Video Tutorial). PA. https://www.youtube.com/watch?v=_8YW2reAQtM n.a. [Howcast]. (June 3, 2013). How to Demonstrate Air Resistance. (Video). https://www.youtube.com/watch?v=O-KYLXp2MG4

n.a. [Howcast]. (June 5, 2013). *How to Do the Paper Book Tower Experiment. Science Project.* (Video). https://www.youtube.com/watch?v=UeB5XhQ2FL4

n.a. [Office Playground]. (March 4, 2011). Balancing Eagle. (Video Tutorial) https://www.youtube.com/watch?v=uptSbW0Cwl8

n.a. (November 29, 2013). Science Experiment: Center of Gravity – Balance a Pop Can. (Video).http://www.indypl.org/kids/blog/?p=8933

n.a. [Sick Science!]. (October 5, 2010). The Coin Drop – Sick Science! #005. (Video Tutorial). https://www.youtube.com/watch?v=qq1Whusk8No

Shafter, Jeremy. (March 31, 2016). *Easy $1 Balancing Eagle.* (Video Tutorial) https://www.youtube.com/watch?v=yRN-AWenFqc

Sprangler, Steve. (2018). The Egg Drop. (Video Tutorial). https://www.stevespanglerscience.com/lab/experiments/egg-drop-inertia-trick/

Sprangler, Steve. (2018). The Spinning Penny. (Video Tutorial). https://www.stevespanglerscience.com/lab/experiments/spinning-penny/

Yeany, Bruce. [William Y Smith]. (Feb15, 2017). *Science Experiments-Newton's 3rd law examples with Bruce Yeany* (Video). https://www.youtube.com/watch?v=fzFG2TPlrv8

Origami References

Badamdorj, Ider. (1977). *Sadako and the Thousand and One Paper Cranes*. G.P. Putman's Sons. New York City.

Callahan, Sophia. (October 16, 2014). *8 Artists Pushing Origami to the Extreme*. [Online Article]. Retrieved from https://creators.vice.com/en_us/article/qkwkmv/8-artists-pushing-origami-to-the-extreme

Choo, Carlson. [Carlson Choo – Malaysian Origami]. (March 25, 2017). *Create Origami Elephant With Treemaker – Tutorial*. [Video Tutorial] Malaysia. https://www.youtube.com/watch?v=oLBH47WYrec

Dambrogio, Jana. (2014). *Historic Letterlocking: The Art and Security of Letter Writing*. [Article]. MIT, Massachusetts. http://letterlocking.org/categories

Demaine, Erik and Tachi, Tomohiro. (July 4, 2017). *Origamizer: A Practical Algorithm for Folding Any Polyhedron.* [Book]. MIT, Massachusetts.

Diaz, Jesus. (July 19, 2017). *If you fold a paper in half 103 times it'll get as thick as the Universe.* [Video and Article]. Gizmodo. https://sploid.gizmodo.com/if-you-fold-a-paper-in-half-103-times-it-will-be-as-thi-1607632639

Elchinger, John. (May 15, 2009). *Experimenting with Force and Motion Using Origami Frogs.* Arlington, Virginia: NSTA Press.

Engel, Peter. (August 18, 1994). *Origami from Angelfish to Zen.* Dover Publications. NY.

Fuse, Tomoko. (April 10, 2018). *Tomoko Fuse's Origami Boxes*. North Clarendon, VT: Tuttle Publishing.

Gao, Wei, Ramani, Karthik, Cipra, Raymond & Siegmund, Thomas. (September 4, 2013). *Kinetogami: A Reconfigurable, Combinatorial, and Printable Sheet Folding*. Journal of Mechanical Design.

Hardesty, Larry. (June 12, 2017). *Origami anything: New algorithm generates practical paper-folding pattern to produce any 3-D structure*. MIT News Office. Massaschusetts.

Hawkes, E. et al. (July 13, 2010). *Programmable Matter by Folding.* National Academy of Science of the United States of America.

Higginson, W., & Colgan, L. (2001). Algebraic thinking through origami. *Mathematics Teaching in the Middle School*, *6*(6), 343.

Hull, Thomas. (2013). *Project Origami: Activities for Exploring Mathematics*. New York: CRC Press.

Lang, Robert. J. (2007). *The Science of Origami*. Physics World, *20*(2), p. 30–31.

Ma, J. You, Z. (2011). The Origami Crash Box. In *Origami 5: Fifth International Meeting of Origami Science, Mathematics, and Education* (p. 646). Retrieved from http://books.google.com/books?hl=en&lr=&id=r-k4GSYaV5YC&pgis=1

Martinez, R. V., Fish, C. R., Chen, X. & Whitesides, G. M. (2012). Elastomeric Origami: Programmable Paper-elastomer Composites as Pneumatic Actuators. Wiley Online Library. Retrieved from https://doi.org/10.1002/adfm.201102978

Neville, R. M., Scarpa, F., & Pirrera, A. (2016). *Shape Morphing Kirigami Mechanical Metamaterials.* Scientific Reports. Retrieved from https://doi.org/10.1038/srep31067.

Oka, Hideyuki, and Sakai, Michikazu. (March 1, 1975). *How to Wrap Five Eggs (1st Edition).* Boston, MA: Shambhala Publications, Weatherhill.

Ou, Jifei, Skouras, Melina, Vlavianos, Nickolaos, Hiebeck, Felix, Cheng, Chin-Yi, Peters, Jannik and Ishii, Hiroshi. *aeroMorph* [Video] MIT Media Lab, Tangible Media Group. https://tangible.media.mit.edu/project/aeromorph/

Sokol, Zach. (June 3, 2014). *Watch Micro Origami Self-Assemble with a Drop of Water*. University of Twente. Netherlands. https://creators.vice.com/en_us/article/78ev7b/watch-micro-origami-self-assemble-with-a-drop-of-water

Stewart, Jessica. (April 5, 2017). *11 Cutting-Edge Origami Artists Who Are Masters of Paper Folding.* (Article). https://mymodernmet.com/contemporary-origami-artists/

Sung, Cynthnia, and Rus, Daniela. (Feb 27, 2015). *Foldable Joints for Foldable Robots.* Cambridge, Massachusetts Institute of Technology. Journal of Mechanisms and Robotics.

Thomas, Evan. (April 28, 2017). *Self-Folding Origami Could Lead to Self-Folding Robots.* [Article and Video File]. Retrieved from https://www.newsy.com/stories/self-folding-origami-could-lead-to-better-robots/

Turner, Nicholas, Goodwine, Bill and Sen, Mihir. (2016). *A Review of Origami Applications in Mechanical Engineering.* Sage Journals. Retrieved from http://journals.sagepub.com/doi/abs/10.1177/0954406215597713.

Wares, A. (2011). Using origami boxes to explore concepts of geometry and calculus. *International Journal of Mathematical Education in Science and Technology*, *42*(2), 264–272. https://doi.org/10.1080/0020739X.2010.519797

Origami Lectures and Talks

Adams, Sara. [happyfolding.com-enjoy origami online.] (September 8, 2017). *How to be a better origami teacher: Lessons learned from making video tutorials.* [Video Talk]. Germany. https://www.youtube.com/watch?v=jurFXVS6euo

Kamien, Randall. (February 7, 2018). Mathematics of Paper. [Lecture]. Physics and Astronomy Departments, University of Pennsylvania, PA.

Lang, Robert. (2008). *Robert Lang: Math and Magic of Origa*mi [Video file]. Retrieved from https://www.ted.com/talks/robert_lang_folds_way_new_origami

Yang, Shu. (April 18, 2018). Foldable and Responsive Soft Metamaterials. [Lecture]. Materials Science & Engineering Department, University of Pennsylvania, PA.
Prakash, Manu. (June 2012). *A 50-cent microscope that folds like orgami*. [Video]. https://www.ted.com/talks/manu_prakash_a_50_cent_microscope_that_folds_like_origami?language=en.

Wali, Fadi Al. (April 19, 2017). *"I love to teach Origami" – Syrian refugee find purpose in exile.* UNHCR, the UN Refugee Agency. Za'atari, Syria and Jordan. https://www.youtube.com/watch?v=r9pdrstfVpQ

Origami Video and Blog Tutorial Links

(Aired February 15, 2017, Expired February 14, 2020). NOVA. Thirteen Media with Impact. https://www.thirteen.org/programs/nova/nova-origami-revolution-episode/

Gigandet, Stephane. (February 18, 2016). [Origami Plus – Easy Origami Tutorials]. *How to Make a Very Easy Origami Sailboat Tutorial (Traditional model) Only 2 folds!* France. https://www.youtube.com/watch?v=NcieP3uy4Dc

Grobe, Fritz and Voltz, Stepent. (n.d.) *Make Your Own Sticky Note Waterfalls*. [Video]. http://www.eepybird.com/featured-video/build-your-own-sticky-note-waterfalls/

Karyn. (2018). *Leap Frog Math Game & Frog Origami.* (Blog, Instructions). Monique B. Design. https://teachbesideme.com/leap-frog-math-gam

Lilypop. (January 14, 2015). *Expanding /Collapsing Origami* (Blog, Instruction) http://www.instructables.com/id/Expandingcollapsing-origami-bracelet/

Naskashima, Jo. (March 13, 2014). *Interactive Origami Sculpture* [Video]. Instructables. http://www.instructables.com/id/Interactive-Origami-Sculpture/

Naskashima, Jo. [Jo Nakashima-Origami Tutorials]. (April 24, 2016). Origami Frog [Video File]. Retrieved from https://www.youtube.com/watch?v=Vlb2udqPx-M

Naskashima, Jo. [Jo Nakashima-Origami Tutorials]. (Dec. 1, 2011). *Origami Slinky* [Video]. https://www.youtube.com/watch?v=ZDs97UoCVgE&list=PL2F923F49A2E9D8AD

Naskashima, Jo. [Jo Nakashima-Origami Tutorials]. (September 20, 2012). *Origami Spring into Action (Jeff Beynon)* [Video File]. https://www.youtube.com/watch?v=ZDs97UoCVgE&list=PL2F923F49A2E9D8AD

Naskashima, Jo. [Jo Nakashima-Origami Tutorials]. (April 27, 2016). *Origami Alphabet* [Playlist 50 Video]. https://www.youtube.com/playlist?list=PL0FAA790A9E1EFEFB

Naskashima, Jo. [Jo Nakashima-Origami Tutorials]. (May 23, 2010). *Origami Moving Cubes using Sonobe units* [Video]. https://www.youtube.com/watch?v=7A_4e-_J714

Naskashima, Jo. [Jo Nakashima-Origami Tutorials]. (March 20, 2018). *Origami Slinky – Non-Modular Version* [Video]. https://www.youtube.com/watch?v=QU2yoRxzuVo

n.a. [Easy Origami]. (July 29, 2017). *Origami: DNA- Instruction in English (BR).* [Video]. https://www.youtube.com/watch?v=pB0FMshudqE

n.a. [eHowArtsAndCraft]. (December 20, 2012). *How to Make an Origami Frog: Simple & Fun Origami.* (Video). https://www.youtube.com/watch?v=ZHTHvQnycKE

n.a. [PaperFold]. (July 20, 2015) *Infinite Rotating Tetrahedron Flexagon –DIY Modular Origami Tutorial*. [Video]. India. https://www.youtube.com/watch?v=db8PniE4PmQ n.a. Bubblegumsquish. (February 4, 2017). *DIY Sticky-Note Slinky.* [Video Tutorial]. https://www.youtube.com/watch?v=SFZIyTU2174

n.a. [Paper Folds – Origami & Craft.] (January 8, 2017). 20 in 1 Origami (20 Origami models from one paper)—Tutorial from Paper Folds. India. https://www.youtube.com/watch?v=UhjDar0YdAo,

Pham, Henry. (October 21, 2016). *Paper Boat that Floats on Water – Origami Sailing Boat Tutorial.* U.S. A. https://www.youtube.com/watch?v=jWlVHrTvqes

Shafer, Jermey [Origamics]. (July 29, 2017). *Origami Transforming Flexahedron! Easy Method.* [Video]. https://www.youtube.com/watch?v=58hqKPLJYtk

Shingu, Fumiaki. (n.d.). Box 1 (Instruction Diagram). https://en.origami-mobile.com/traditional/11-box/zu.html

Trumbore, Ben. (April 3, 2016). *Spring Into Action*. [Video and Blog]. http://trumbore.com/spring/

wonka. (March 20, 212). *383: Slinky*. Setting the Crease: PDub's Paper-Based [Blog and Instructions] Procrastinaiton Project. http://www.wonko.info/365origami/?p=2800

Weidner, Wolf. [Tavin's Origami Instructions]. (May 24, 2009). *Origami: jumping frog*. (Video). Germany. https://www.youtube.com/watch?v=rc9lVHvfzMY

Teaching References, Instructions and Tips:

Blacker, Kara. (December 15, 2016). Debunking the Left-Brain/Right-Brain Myth. [Blog]. Science of Learning Institute. Johns Hopkins University. http://scienceoflearning.jhu.edu/science-to-practice/resources/debunking-the-myth-about-left-brain-right-brain-learning-styles

Demaine, Erik, Demaine, Martin and Steckles, Katie. (2016). *Simple Fold & Cut Font*. Massachusetts Institute of Technology. http://erikdemaine.org/fonts/simplefoldcut/

Domingo, Muriel. (June 22, 2018). *Dieter Rams: 10 Timeless Commandments for Good Design.* Interaction Design Foundation. Denmark. https://www.interaction-design.org/literature/article/dieter-rams-10-timeless-commandments-for-good-design

Gallagher, Kelly. (2004). *The 30-15-10 List.* (pdf file). Deeper Reading. Stenhouse Publishers https://www.rtsd.org/cms/lib/PA01000218/Centricity/Domain/933/30-15-10_list-prefix-root-words-suffix.pdf

Juuti, K., Lavonen, J., Uitto, A. et al. (2010). *Science Teaching Method Preferred by Grade 9 Students in Finland*. International Journal of Science and Math Education. Springer Netherlands. https://doi.org/10.1007/s10763-009-9177-8

Levenson, George. (n.a). *The Educational Benefits of Origami.* Retrieved from http://home.earthlink.net/~robertcubie/origami/edu.html

Mazzola, Lisa. (Spring 2018). Art & Ideas: Teaching with Themes. Museum of Modern Art. Retrieved from https://www.coursera.org/moma

Moeny, Jordan. (March 27, 2015). *Finland to Reduce Role of Academic Subjects Through "Phenomenon" Teaching.* [Blog] Education Week Teacher. http://blogs.edweek.org/teachers/teaching_now/2015/03/finland-interdisciplinary-phenomenon-teaching.html

Moje, Steven. (n.d). *Science Experiments with Paper*. [pdf file]. http://www.arvindguptatoys.com/arvindgupta/paperscience1.pdf

Morrissey, Deirdre. (June 11, 2018). *Prefixes, Roots, and Suffixes.* (Blog, List, Game). http://www.bloggiwog.com/?page_id=231

n.a., (n.d.), Create A Greek Or Latin Root Superhero. (pdf file). http://www.sarahsmithelementary.com/faculty/rawlsm/Greek%20and%20Latin%20Root%20Superhero%20PDF.pdf

n.a., n.d. *Jabberwocky.* Alice-in-Wonderland.net. (Poem Analysis). http://www.alice-in-wonderland.net/resources/analysis/poem-origins/jabberwocky/

n.a, (n.d.). *Effective Conferencing Skill.* Cengage Learning. Houghton Mifflin Company. https://college.cengage.com/instructors/ins_teachtech_foundations_module_effconf.html

n.a. n.d. *Egg Drop Project.* www.smusd.org/cms/lib3/CA01000805/.../Egg%20Drop%20ProjectDN2014.docx

n.a. (n.d.), *Project Egg Drop Rubric.* http://studylib.net/download/8510711

n.a. (n.d). *Mastery Learning: A guide to the key principles of mastery. [pdf File]*. https://readingallthebooksuk.files.wordpress.com/2016/01/mastery-handbook-jfa1.pdf

n.a. (2011). *Origami Base-ics*. Creased [Magazine For Paper Folders]. Retrieved from http://creased.com/baseics/pdf/baseics.pdf

n.a., n.d. *Word Parts. Prefixes, Roots & Suffixes.* Monterey Peninsula College, Reading Center. (pdf file). https://www.mpc.edu/home/showdocument?id=12804

Ramirez, Ainissa. (April 29, 2015). *5 Reasons Why Origami Improves Students' Skills*. Edutopia. George Lucas Educational Foundation. https://www.edutopia.org/blog/why-origami-improves-students-skills-ainissa-ramirez

Wilson, Frederic R., and Julian, Timothy. (2016). *STREAMS: Integrated Curriculum*. [pdf file]. Teaching Green: The Middle Years. Making Interdisciplinary Connections. Huntingdon, PA. Retrieved from http://www.earthrangers.org/wp-content/uploads/2016/08/streams_integrated_curriculum.pdf

Appendix List

Project Introductions:

Appendix P.1.1: Egg Container Project Challenge (Pages 1 and 2)
Appendix P.1.2: The Egg Container Paper Design, Lab Report Assignment
Appendix P.1.3: Egg Container Grading Sheet/Rubric
Appendix P.1.4: Simple Origami Box Instructions
Egg Container Assignment adapted from http://studylib.net/download/8510711
www.smusd.org/cms/lib3/CA01000805/.../Egg%20Drop%20ProjectDN2014.docx

Appendix P.2.1: Superhero Assignment
Appendix P.2.2: Superhero Grading Sheet/Rubric
Appendix P.2.3: List of Prefixes, Roots and Suffixes
Appendix P.2.4: Template for Letter A "Fold and One Cut" Technique (Eric Demaine)
Superhero Assignment adapted from http://www.bloggiwog.com/?page_id=231
http://www.sarahsmithelementary.com/faculty/rawlsm/Greek%20and%20Latin%20Root%20Superhero%20PDF.pdf

Science Lessons:

Appendix L1: First Law Questions and Recording Sheet (Pages 1 and 2)
Appendix L2: Second Law Questions and Recording Sheet (Pages 1 and 2)
Appendix L3.1: Third Law Questions and Recording Sheet (Pages 1 and 2)
Appendix L3.2: 3^{rd} Law, Identify Action and Reaction (Pages 1 and 2)
Appendix L3.3: 3^{rd} Law, Origami Jumping Frog
Appendix L3.4: 3^{rd} Law, Origami Slinky
Appendix L3.5: 3^{rd} Law, Post-It Slinky and Origami Spring
Questions adapted from https://www.sas.upenn.edu/~kennethp/nkdievid2.pdf
https://www.cusd80.com/cms/lib/AZ01001175/Centricity/Domain/8456/Newtons%20Laws%20Worksheet%20KEY.pdf
Appendix L4: Ideas & Tips to Set Up Origami Class Challenges

Assessments:

Appendix A5.1: Unit Assessment: Newton's Laws of Motion Questions
Appendix A5.2: Unit Assessment: Individual Conference Recording Sheet
Appendix A6: Unit Assessment: Presentation Grading Sheet

Appendix P.1.1 (Page 1)
The Egg Container Paper Design Project

Student's Name:________________________________ Date Due:_______________

Goal: Design and construct a paper container to protect the egg from a fall of over 3 meters (9 feet) from the ground.

Objective: SWBAT to design and build an origami paper container that will protect a fragile egg from cracking under stressful landing and accident conditions IOT understand how energy is converted from potential to kinetic energy, and the amount of work done on the container versus the work done on the egg.

Essential Question: Based on the fragility of an egg, what design concepts need to be considered to protect an egg during a drop from over 3 meters (9 feet) high?

Questions to be remindful of as you design your container:
Should your container be made rigid; or is it better if the paper collapses?
Should the egg be able to move, or should it be held immobile?
What types of structures will absorb the shock of an impact?
How can it be designed to withstand multiple drops from successively greater heights?

Background Information: To reduce the effect of impacts due to accidents (primary in the automobile industry), engineers and scientists have been using origami to design foldable airbags and collapsing steering wheels. **Preparation:** Watch YouTube videos to learn how to make simple origami boxes of different shapes and designs.

Construction Rules:

- The final container must be an original design.
- **Required Material**: **PAPER ONLY**, any sizes and any thickness can be used. **NO tape** or the design will be disqualified.
- The design must be able to fit within a 12" cube. Once the device is released, it may take any shape or size. There will be no physical contact with the device once it has been released.
- The egg must be put into the design on the day of the competition. The design must allow for easy opening and inspection of the egg. Opening and closing of the packages will be accomplished in the same period of time (2 minutes).
- Be prepared to clean up any mess, if necessary.

Remember to figure out the followings:

- Mass of container plus egg (in kg)
- Acceleration of container during its fall (in m/s^2)
- Time of fall (in s)
- Force of impact (in N)

Appendix P.1.1 (Page 2)
Egg Container Brainstorm Ideas (20 points)

Student's Name:_________________________________ Date Due:______________

Brainstorm, Sketch and Label 4 possible Egg Container Designs
Points Earned (Max. 20 points):_____________________

Appendix P.1.2
The Egg Container Paper Design: Lab Report Assignment

Student's Name:________________________________ Date Due:_______________

AFTER THE DROP

In 3 to 5 paragraphs discuss the following (you may handwrite or type):

1. **Summarize how you decided upon your final design. (10 points)**
How did your research influence your design?
Explain how you built your container.
Discuss any issues you came upon as you were building it.
Did you do any practice drops before drop day in the classroom?

2. **Conclusion (10 points):**
What happened on drop day for your container?
Why do you think your container has this result?
If you could do this project again, what would you change and why?

3. **Scientific Research (10 points):**
Discuss the physics behind how your egg freefall.
Explain how concepts such as force, motion, inertia, center of gravity, mass, acceleration, action and reaction, etc.
Report should explain how Newton's Three Laws of Motion relate to the project.
Take you time explaining the physics and do a quality job to earn the most points.

4. Sketch and **label** your final design **(10 points).**

Give your container a name:________________________________

Appendix P.1.3
Egg Container Grading Sheet/Rubric

Student's Name:____________________________________ Date Due:________________

Egg Paper Container Assignment	**Points Possible Points**	**Points Received**
Brainstorm Ideas (4 options)	20	
Design Dimension (Less than 12")	10	
Design Aesthetic	10	
Mass (Light or heavy?)	10	
Drop (Egg intact or broken? Successful?)	10	
Final Report (also a writing grade)	20	
Final Design Stretch & Label	10	
Bonus Points	10	
Violations (late, use excessive amount of tape, etc.)	**-10**	
	Total (of 100):	

Appendix P.2.1: Superhero Assignment

Student's Name:_________________________________ Date Due:_______________

Create a Greek or Latin Prefix, Root and/or Suffix Superhero

Rationale: 97% of the words that students will encounter are made up of 30 prefixes, 30 roots, and 30 suffixes. 70% of these words can be defined using word parts and 30% can be defined using context clues. If you know the meanings of these prefixes, roots and suffixes, you will likely to have the ability to determine the meaning of unknown words you encounter while reading. Determining the meaning of phrases is a critical skill with implications for all later grades and disciplines.

Assignment: In this project assignment you will use the prefix, root and suffix of your choice to inspire the creation of a superhero. Your costume should reveal clues to which these word parts represent. For example, a crown of pencils might reveal the root "graph", a cape with the map of the world might reveal the root "geo", a mask of moons and stars might reveal the root "ast". Be creative!

Requirement: Use either Erik Demaine's "Fold and One Cut" technique or Jo Nakashima's folding technique to make an origami-inspired letter emblem for your your superhero cosutme. http://erikdemaine.org/fonts/simplefoldcut/
http://thekidshouldseethis.com/post/fold-cut-theorem-cut-any-shape-from-only-one-cut
https://www.youtube.com/watch?v=rkT6dKXuIr8&list=PL0FAA790A9E1EFEFB

Superhero Name:____
Superhero Power(s) based on the meaning of prefix, root and/or suffix:
My Superhero has the superpowers to____
____
____
____

Design a Costume (You must include at least one of the 6 options)
____Mask ___Hat ____Gloves ____Cape ____Top ____Pants/Shirts

List at least 10 words using your chosen prefixes, roots and/or suffixes:

1.____________ 2.____________ 3.____________ 4.____________ 5.____________

6.____________ 7.____________ 8.____________ 9.____________ 10.___________

Speech: Write a monologue (one paragraph) for your Superhero. Use many of the words you listed to explain how you acquired your powers and a time when you saved the day using these superpowers. **Bonus points:** Come to school dress as your character or bring your costume in a bag so you can easily change into it for your monologue.

Appendix P.2.2: Superhero Grading Sheet/Rubric

Student's Name:___________________________________ Date Due:______________

Superhero Assignment	**Points Possible Points**	**Points Received**
Brainstorm Ideas Prefix:____________ Root:_____________ Suffix:____________	12	
Superhero Name	10	
Superhero Power	10	
Costume	20	
10 words with prefix, root and/or suffix	10	
Letter Origami Emblem	20	
Monologue (also a writing grade)	20	
Bonus Points (Wear costume)	10	
Violations (late, no emblem, etc.)	**-10**	
	Total (of 100):	

Student's Name:___________________________________ Date Due:______________

Appendix P.2.3:

List of 30 Prefixes, 39 Roots and 24 Suffixes

Prefixes						**Suffixes**			
a, ab,abs	dis, dif, di	in	ob	Se		-able, -ible	-dom	-ive	-acy
ad, a, ac, af, ag, an, ar, at, as	epi	inter	omni	Sub		-er, -or	-sion, -tion	-logue, -log	-ance, -ence
bi, bis	equi	mal, male	preter	Super		-fy	-ness	-ish	-al
circum	ex, e	mis	pro	Trans		-ism	-ship	-ate	-ity, -ty
com, con	hyper	mono	re	un, uni		-ist	-tude	-ize, -ize	-esque
de	hypo	non	retro	un (uhn)		-less	-ful	-ment	-ious, -ous

Roots	meaning	**Roots**	Meaning	**Roots**	Meaning
bas	low	fac, fact	make, do	spec, spect	See
cap, capt	take, seize	graph	Write	Tact	Touch
cred	believe	log	word, study of	Ten	Hold
dict	speak	mort	die, death	Therm	Heat
duc, duct	lead	scrib, script	Write	Ver	True
ast	**star**	ped	Foot	Phon	Soung
audi, aud	hear	struct	Build	Luc	Light
auto	self	cycl	Circle	Port	Carry
aqu	water	vit, viv	Alive	Bio	Life
mater	mother	bene	Good	Mal	Bad
chrono	time	meter	Measure	Photo	Light
grad, gress	step	rupt	break, burst	vid, vis	See
jur, jus	law	geo	Earth	Tele	far off

Brainstorm Your Superhero Characteristics Based on Your Selected Prefixes, Roots and Suffixes

Source https://www.rtsd.org/cms/lib/PA01000218/Centricity/Domain/933/30-15-10_list-prefix-root-words-suffix.pdf

Appendix L1: **First Law** Questions and Recording Sheet (Page 1)

Date Due:________________ **Group #________________**

Student Names:
1)_______________________2) ______________________3)_______________________

4) ______________________ 5)______________________ 6)_______________________

Experiment Title: ____

Video Website: ____

List of Materials: ____

____

Steps of the Procedures:____

____

____

____

____

Observation: ____

____

____

____

Explain how this experiment is related to Newton's Law of Motion.

____

____

____

Appendix L1:

First Law Questions and Recording Sheet (Page 2)

https://www.nwasco.k12.or.us/cms/lib04/OR01001464/Centricity/Domain/97/Newton_s%20laws%20worksheet.pdf

Student's Name:________________________________ Date Due:______________

1. What does Newton's 1st Law of Motion say?

____

____

2. Put Newton's 1st Law of Motion in your own words.

____

____

3. Newton's first law of motion is also known as the Law of ____________________.

4. Complete the sentence below:

Newton's First Law of Motion says that an object that IS **NOT MOVING**, or is at

_________________, will stay at ____________________, **AND** an object that **IS MOVING**

will keep moving with constant____________________, which means at the same

____________________ and in the same___________________, **UNLESS** an

___________________________ force acts on that object.

5. What is inertia?____

6. What property of an object determines how much inertia it has?

____

7. Which of the following has the most inertia? Circle one.

bowling ball tennis ball hammer feather

Appendix L2:

Second Law Questions and Recording Sheet (Page 3)

Date Due:_______________ **Group #_______________**

Student Names:
1)______________________2) _____________________3)______________________

4) _____________________ 5)_____________________ 6)______________________

Experiment Title: ____

Video Website: ____

List of Materials: ____

____

Steps of the Procedures:____

____

____

____

____

Observation: ____

____

____

____

Explain how this experiment is related to Newton's Law of Motion.

____

____

____

Appendix L2:

Second Law Questions and Recording Sheet (Page 4)

https://www.nwasco.k12.or.us/cms/lib04/OR01001464/Centricity/Domain/97/Newton_s%20laws%20worksheet.pdf

1. What does Newton's 2nd Law of Motion say?

____

____

2. Put Newton's 2nd Law of Motion in your own words.

____

____

3. Newton's second law of motion is also known as the Law of ____________________.

4. Complete the sentence below:

Newton's second law says that when an ___________________ force is applied to a _________________, it causes it to ________________________. The greater the force that is applied, the _________________ the acceleration. The lesser the force that is applied, the ___________________ the acceleration. If the same force is applied to an object with a large mass, it will have a _______________ acceleration. If the same force is applied to an object with a small mass, it will have a _________________ acceleration.

5. The equation that is used to solve second law problems is F = ma. What do each of the variables mean? F = _______________ m = ____________ a = __________________

6. What unit of measurement must be used with each variable?

F = ______________ m = ______________ a = _________________

Appendix L3.1:

Third Law Questions and Recording Sheet (Page 5)

Date Due:_______________ **Group #**_______________

Student Names:

1)______________________**2)** _____________________**3)**______________________

4) _____________________ **5)**_____________________ **6)**______________________

Experiment Title: ____

Video Website: ____

List of Materials: ____

____

Steps of the Procedures:____

____

____

____

____

Observation: ____

____

____

____

Explain how this experiment is related to Newton's Law of Motion.

____

____

____

Appendix L3.1:

Third Law Questions and Recording Sheet (Page 6)

https://www.nwasco.k12.or.us/cms/lib04/OR01001464/Centricity/Domain/97/Newton_s%20laws%20worksheet.pdf

1. What does Newton's 3rd Law of Motion say?

____

____

2. Put Newton's 3rd Law of Motion in your own words.

____

____

3. Newton's third law of motion is also known as the Law of ____________________.

4. Newton's third law says that every time there is an ___________________________

force, there is also a ________________________ force that is ______________________

in size and acts in the _____________________________ direction.

5. Newton's third law states that forces must ALWAYS occur in _____________________.

6. Listed below are ACTION forces. Tell the REACTION force.

- Your bottom pushing on your desk seat. Reaction:_____________________
- A bat hitting a baseball Reaction:______________________
- Your finger texting on your phone screen Reaction:______________________

7. What is friction? ____

8. List the **four** types of friction.

1)_____________ 2)_______________ 3)______________ 4)________________

Appendix L3.2:

Third Law: Identify Action and Reaction (Page 7)

Direction: #1 and #2 are done for you as examples. Identify the **action and reaction** for each demonstration or situations. For #1 to #5, use the video "Science Experiments- Newton's 3rd law examples with Bruce Yeany" to guide you.

Describe Newton's 3rd Law of Motion before you complete the chart.

____

____

Demo.	Experiment	Action	Reaction
#1	Scale	A person standing (pushing down) on the scale	The scale pushing up to the foot of the person
#2	Balloon	A person blows air into a balloon	When release, the air push out of the balloon
#3	Person Jumping on the Ground		
#4	Person Jumping on a Skateboard		
#5	Toy Car on Cardboard on Rolling Pencils		
#6	Person pushes against a wall		
#7	Rocket Launch		
#8 Why the book is at the state of equilibrium?	A book rests on a table. **Equilibrium** is a state in which opposing forces are balanced.		
#9	What happens to a person without a seatbelt during a car crash?		
#10	What happens to a person wearing a seatbelt during a car crash?		

Appendix L5.1: Unit Assessment
Newton's Laws of Motion Questions (Page 8)

Direction: Answer the following questions using complete sentences. Be sure to use Newton's Laws of Motion in your answers.

1. What happens according to Sir Issac Newton if you let an untied balloon go?

2. Describe what happens if you are riding a skateboard and hit something (like a curb) with the front wheels.

3. Describe what happens if you push someone who is the same size as you. What happens if he or she pushes back?

4. Describe why an archer would hold the bow and arrow next to his or her body while shooting at a target.

5. What is another name for the first law of motion? Why is it given that name?

6. Why should we wear seatbelts – use one of Newton's Laws in your answer?

7. Using Newton's laws explain why heavier objects require more force than lighter objects to move or accelerate them?

8. How can Newton's laws be used to explain how rockets are launched into space?

9. Explain how each of Newton's laws affects a game of Tug of War.

10. How do Newton's laws affect your daily life?

Answer Key: **Appendix L5.1: Unit Assessment**

Source:https://www.shakopee.k12.mn.us/cms/lib07/MN01909221/Centricity/Domain/293/Laws%20of%20Motion%20Questions%20KEY.pdf

1. What happens according to Newton if you let an untied balloon go? **Third Law:** Air will rush out of the balloon forcing it to move through the air in the opposite direction, but equal in force.

2. Describe what happens if you are riding a skateboard and hit something (like a curb) with the front wheels. **First Law:** Your body will keep moving forward and fly off your skateboard since the curb only stops the board, not yourself.

3. Describe what happens if you push someone who has more mass than you. What happens if he or she pushes back? **Second Law:** If you put force on someone who has more mass than you, force will be put back on you. Because of the other person's mass, you most likely will not have enough force to make him or her accelerate. If someone pushed you, you most likely would move in the direction of the force, since the other person has more mass.

4. Describe why an archer would hold the bow and arrow next to his or her body while shooting at a target. When the archer pull the bow and arrow apart, it forces the arrow out of the bow, but at the same time, the bow is forced in the opposite direction of the arrow (towards the archer). The arrcher's shoulder is a new force that is introduced in order to keep your bow from flying away from him or her.

5. What is another name for the first law of motion? Why is it given that name? Law of inertia (First Law): It is given that name because inertia is the tendency of an object to resist any change in its motion until an unbalanced force acts on it.

6. Why should we wear seatbelts – use one of Newton's Laws in your answer? We should wear seatbelts so if we are in an accident our body doesn't keep moving at the same speed and in the same direction that the car was going. A new force would be introduced to our bodies (the seatbelt) in order to keep our bodies in place.

7. Using Newton's laws explain why heavier objects require more force than lighter objects to move or accelerate them? Second Law: Something with more mass moving at the same acceleration as a lighter object would require more force to change its speed or change its direction. Our formula F=m x a is derived from Newton's second law.

8. How can Newton's laws be used to explain how rockets are launched into space? **Third law:** when the rocket pushes out fire with a specific amount of force, the rocket will move in the opposite direction, but with the same amount of force, causing the rocket to shoot up into the air.

9. Explain how each of Newton's laws affects a game of Tug of War. **First Law:** The rope will stay in the same place until the tugging starts (when a new force is introduced). **Second Law:** We could measure a team's force that they can pull the rope based on their body masses and the acceleration that they are causing the rope to move at. **Third Law:** One team pulls the rope towards themselves with a certain amount of force and the opposing team is also putting force on the rope. The same amount of force is applied from the ground to the people as they are putting on the ground.

10. How do Newton's laws affect your daily life? Answers will vary, but EVERYTHING that happens in our lives can be connected back to one of Newton's 3 laws of motion since force is involved in everything.

Appendix L5.2: Individual Conferencing Record Sheet

Date:	
Student's Name & Grade:	
Purpose of Today's Conference:	
Teacher's Observations:	
Instructional Needs:	
Student's Goals for Future:	

Appendix L5.2: Individual Conferencing Record Sheet

Copyright © Cengage Learning

Date:	
Student's Name & Grade:	
Purpose of Today's Conference:	
Teacher's Observations:	
Instructional Needs:	
Student's Goals for Future:	

Appendix A6: Unit Assessment:
Oral Presentation Grading Sheet

Name: ______________________________________ Score: ________(out of 16 points)

Project:_____________________________________Subject:_____________________

General Oral Presentation Rubric

	4 Excellent	3 Good	2 Fair	1 Needs Improvement
Delivery	Holds attention of entire audience with the use of direct eye contact, seldom looking at notes. Speaks with fluctuation in volume and inflection to maintain audience interest and emphasize key points	Consistent use of direct eye contact with audience, but still returns to notes. Speaks with satisfactory variation of volume and inflection	Displays minimal eye contact with audience, while reading mostly from the notes. Speaks in uneven volume with little or no inflection	Holds no eye contact with audience, as entire report is read from notes. Speaks in low volume and/ or monotonous tone, which causes audience to disengage
Content/ Organization	Demonstrates full knowledge by answering all class questions w. explanations & elaboration. Provides clear purpose and subject; pertinent examples, facts, and/or statistics; supports conclusions/ideas with evidence	Is at ease with expected answers to all questions, without elaboration. Has somewhat clear purpose and subject; some examples, facts, and/or statistics that support the subject; includes some data or evidence that supports conclusions	Is uncomfortable with information and is able to answer only rudimentary questions. Attempts to define purpose and subject; provides weak examples, facts, and/ or statistics, which do not adequately support the subject; includes very thin data or evidence	Does not have grasp of information and cannot answer questions about subject. Does not clearly define subject and purpose; provides weak or no support of subject; gives insufficient support for ideas or conclusions
Enthusiasm/ Audience Awareness	Demonstrates strong enthusiasm about topic during entire presentation. Significantly increases audience understanding and knowledge of topic; convinces an audience to recognize the validity and importance of the subject	Shows some enthusiastic feelings about topic. Raises audience understanding and awareness of most points	Shows little or mixed feelings about the topic being presented. Raises audience understanding and knowledge of some points	Shows no interest in topic presented. Fails to increase audience understanding of knowledge of topic
Comments				