Unit 1: Why do some clothes stick together when they come out of the dryer?

Investigation 1: Why do some things stick together and other things don't? ***NGSS PE:*** HS-PS2-4. Use mathematical representations of Newton's Law of Gravitation and Coulomb's Law to describe and predict the gravitational and electrostatic forces between objects.				
Activity	**What did we observe?**	**What did we figure out?**	**Model/Explanation**	**NGSS Dimensions**
1: What are some examples of things that stick together and things that don't?	• Balloon attracted to the wall after being rubbed with fur • Wig hair standing on end after VdG is turned on • Stack of pie pans flying off the VdG when it is turned on.	Rubbing objects against each other or placing objects on a VdG that is turned on causes them to attract or repel (stick together or push apart).	Contains only observable components, no causal relationships. Charges are modeled as static, matter is continuous, no Coulomb Law relationship present.	DCI: Structure and properties of matter: • The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms. CCC: Cause and effect • Students suggest cause and effect relationships to explain and predict behaviors in complex natural and designed systems. SEP: Asking questions and defining problems Ask questions: • that arise from careful observations of phenomena, or unexpected results, to clarify and/or seek additional information. • to clarify and refine a model, and explanation, or an engineering problem.
2: What are some patterns in how things stick together or push apart?	• Scotch tape activity: investigating how the two pieces of tape interact • Charge simulation: investigating how similar and opposite point charges interact	Opposites attract, likes repel, but no understanding of scientific principles behind the statement	Observable components, might show some causal relationships, charges are modeled as point charges, like charges repel, opposite charges attract.	DCI: same as activity 1 CCC: Patterns: • Observe patterns in systems and cite patterns as empirical evidence for causality in supporting their explanations of phenomena SEP: Planning and carrying out investigations: • Use investigations to gather evidence to support explanations or concepts.
3: What effect do charged objects have	• Plastic bottle attracts paper bits and my	Neutral (uncharged) objects attract to	Same as above, plus: neutral (uncharged) objects	DCI: same as above and *PS1.A Structure and properties of matter:* The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms

on uncharged objects?	hand after being rubbed with fur	positively and negatively charged ones	attract to both charges	CCC: Patterns*:* observe patterns in systems and cite patterns as empirical evidence for causality in supporting their explanations of phenomena SEPs: *Analyzing and interpreting data:* Use tools, technologies and/or models to generate and analyze data in order to make valid and reliable scientific claims *Developing and using models:* Develop, revise and use models to predict and support explanations of relationships between systems or between components of a system.
4: How do I know if something is positively or negatively charged?	Attractive and repulsive interactions between different types of rods after they are rubbed with different types of materials.	Determining the type of charge on each object.	revise explanation of the tape activity to include the type of charge on each tape and justification for the choice of the charge.	DCI: *PS2.B Types of Interactions:* Attraction and repulsion between electrical charges at the atomic scale explain the structure, properties, and transformations of matter, as well as the contact forces between material objects CCC*: Patterns:* Observe patterns in systems and cite patterns as empirical evidence for causality in supporting their explanations of phenomena. SEPs: *Planning and carrying out investigations:* Design an investigation individually and collaboratively and test designs as part of building and revising models, supporting explanations for phenomena, or testing solutions to problems. *Analyzing and interpreting data:* Use tools, technologies and/or models to generate and analyze data in order to make valid and reliable scientific claims
5: How does an object's charge affect its interaction with neutral object?	Various neutral objects interacting with charged objects; balloon sticking to the wall after it is rubbed with fur, simulation with charges	Neutral (uncharged) objects attract to positively and negatively charged ones (continued)	Revised model of electrical interactions (pie pans on VdG) showing charges as point charges, forces as directional arrows, no charge transfer at this point	DCI: PS2.B Types of Interactions: Attraction and repulsion between electrical charges at the atomic scale explain the structure, properties, and transformations of matter, as well as the contact forces between material objects. CCC*: Patterns:* Observe patterns in systems and cite patterns as empirical evidence for causality in supporting their explanations of phenomena. SEP: *Developing and using models:* Develop, revise and use models to predict and support explanations of relationships between systems or between components of a system.

Investigation 2: What are factors that affect the interactions between objects? ***NGSS PE:*** HS-PS2-4. Use mathematical representations of Newton's Law of Gravitation and Coulomb's Law to describe and predict the gravitational and electrostatic forces between objects.				
Activity	**What did we observe?**	**What did we figure out?**	**Model/Explanation**	**NGSS Dimensions**
1: How can charged objects have an effect on each other without touching?	• Arrow made of aluminum foil always points towards the VdG when it is turned on. • Simulation that models electric field around the VdG	Charged objects have electric field around them. Electric field causes attractive and repulsive interactions between objects t a distance (without contact)	The model of electrical interactions will include electric field modeled as pointers to show the direction of force that a positive charge would experience. The color intensity of the pointers may be used to represents the strength of the field at that point in space.	DCI: *Types of interactions:* Forces at a distance are explained by fields (gravitational, electrical, and magnetic) permeating space that can transfer energy through space. CCC*: Patterns:* Observe patterns in systems and cite patterns as empirical evidence for causality in supporting their explanations of phenomena SEP*: Developing and using models:* Develop, revise and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system.
2: How do factors like distance and amount of charge affect interactions between objects?	• Tape bands to a different degree when is brought closer or further away from the VdG • Tape interacts with the balloon after the balloon is rubber with fur: the closer the tape, the more it bends towards the balloon. • Simulations with oppositely charged particles and electric fields	Qualitatively explain and predict how the amount of charge and the distance between two charged objects affects the strength of the electric force between them.	The model includes qualitative Coulomb's relationship: the bigger the charge, and the smaller the distance, the stronger the force	DCI: *Types of interactions:* Forces at a distance are explained by fields that and can be described in terms of the arrangement and properties of the interacting objects and the distance between them. These forces can be used to describe the relationship between electrical fields. CCC: *Cause and effect:* Students suggest cause and effect relationships to explain and predict behaviors in complex natural and designed systems. They recognize changes in systems may have various causes that may not have equal effects. SEP: *Analyzing and interpreting data:* Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution.

3: How does our model of charge interactions connects with variety of phenomena?	• Franklin Bell principle demo using VdG and soda cans.	Neutral objects become charged by contact with other charged objects (charge is transferred through contact). Charged objects become neutral (loose charge) after the charge has been transferred via contact.	The model includes mechanism for how objects become charged at the macro level (charge is modeled as point charge that gets transferred from charged object to the neutral one via contact).	DCI: *Types of interactions:* Forces at a distance are explained by fields (gravitational, electrical, and magnetic) permeating space that can transfer energy through space. CCC: *Cause and effect:* Students suggest cause and effect relationships to explain and predict behaviors in complex natural and designed systems. They recognize changes in systems may have various causes that may not have equal effects. SEP: *Developing and using models:* • Develop, revise and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system. • Develop and/or use multiple types of models to provide mechanistic accounts and/or predict phenomena; and move flexibly between model types based on merits and limitations.

Investigation 3: What are all materials made of?				
NGSS PE: HS-PS1-3. Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles.				
Activity	**What did we observe?**	**What did we figure out?**	**Model/Explanation**	**NGSS Dimensions**
1: Can the same piece of paper be cut into pieces indefinitely?	• Using scissors to cut paper into smaller pieces.	Make predictions about what paper and other objects look like at the microscopic (unobserved) scale)	Start suggesting possible structure of matter at the microscopic scale and think about how charges and structure of matter is related.	DCI: *Structure and properties of matter:* The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms. CCC: *Structure and function:* Students investigate systems by examining the properties of different materials, the structures of different components, and their interconnections to reveal the system's function and/or solve a problem. SEP: *Asking questions and defining problems:* Ask questions • that arise from careful observation of phenomena, or unexpected results, to clarify and/or seek additional information. • that arise from examining models or a theory, to clarify and/or seek additional information and relationships. • to clarify and refine a model, an explanation, or an engineering problem.
2: Does 5+5 always equal 10?	• When water and ethanol is mixed, the resulting volume is less than the sum of the two volumes of the two liquids • Simulation of the water and ethanol lab	Particle model of matter accounts for the observed results of mixing water and ethanol better	Matter (macroscopic objects) are made of particles. At this point, students don't know the structure of those particles, and how charges are accounted or in the structure of matter model	DCI: *Structure and properties of matter:* Matter of any type can be subdivided into particles that are too small to see, but even then, the matter still exists and can be detected by other means. CCC: *Patterns:* Students observe patterns in systems at different scales and cite patterns as empirical evidence for causality in supporting their explanations of phenomena. SEP: *Obtaining, evaluating, and communicating ideas:* • Evaluate the merits and limitations of two different models of the same proposed tool, process, mechanism or system in order to select or revise a model that best fits the evidence or design criteria. • Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system.
3: Is the particle model always better?	• Compress syringe filled with air to a certain point, after	There is space between particles that make up gas	Particle model of matter includes the idea that there is	DCI: *Structure and properties of Matter:* Matter of any type can be subdivided into particles that are too small to see, but even then, the matter still exists and can be detected by other means. A model that shows gases are made of matter particles that are too small to see and that are moving freely around in

	which it cannot longer be compressed no matter how much force you exert. • Compressing syringe simulation		space between particles	space can explain many observations, including the inflation and shape of a balloon and the effects of air on larger particles or objects. CCC: *Scale, Proportion, and Quantity:* Students recognize that patterns observable at one scale may not be observable or exist at other scales and that some systems can only be studied indirectly as they are too small to observe directly. SEP: *Developing and Using Models:* • Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system. • Develop and/or use multiple types of models to provide mechanistic accounts and/or predict phenomena, and move flexibly between model types based on merits and limitations.
4: Which model best supports our observations?	• History of the atom timeline	Bring ideas together as to which model of better (particle or continuous) best explains observations related to mixing ethanol and water and compressing syringe filled with air	Particle model of matter as the final mode: • Matter is made of particles modeled as spheres, no components • Space between particles	DCI: *Structure and properties of matter:* Matter of any type can be subdivided into particles that are too small to see, but even then, the matter still exists and can be detected by other means. CCC: *Scale, Proportion, and Quantity:* Students recognize that patterns observable at one scale may not be observable or exist at other scales and that some systems can only be studied indirectly as they are too small to observe directly. SEP: *Engaging in argument from evidence:* • Evaluate the claims, evidence, and/or reasoning behind currently accepted explanations or solutions to determine the merits of arguments. • Make and defend a claim based on the effectiveness of a design solution that reflects scientific knowledge

Investigation 4: What are nature's building blocks?

HS-PS1-1. Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms.

Activity	What did we observe?	What did we figure out?	Model/Explanation	NGSS Dimensions
1: What are the particles that make up all substances, and how small are they?	• History of the atom timeline • Relative sizes of macroscopic objects, atoms and molecules	• Draw conclusions about relative sizes of atoms, molecules, and various macroscopic objects	Start describing qualitatively relative size of atoms	DCI: *Structure and properties of Matter:* The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms. CCC: *Scale, Proportion, and Quantity:* Some systems can only be studied indirectly as they are too small, to large, too fast, or too slow to observe directly. Students use orders of magnitude to understand how a model at one scale relates to a model at another scale. SEP: *Obtaining, Evaluating, and Communicating Information:* Compare, integrate and evaluate sources of information presented in different media or formats (e.g., visually, quantitatively) as well as in words in order to address a scientific question or solve a problem.
2: If you can't see it, how do you know it's there?	• Mystery box with holes. Laser is used to shine light into the wholes to try and predict what's in the box. • Thompson's experiment simulation to determine electron charge. • History of the atom timeline: discuss plum and pudding model and why it was popular at the time	• Use evidence from experiments to draw conclusions about the structure/shape of objects we cannot directly observe (Mystery box) • Apply the mystery box indirect evidence principle to study simulations that show electrons being show between two oppositely charged plates, and observe how the electron path changes	• Practice to use indirect evidence in developing and revising models/explanations. • Obtain evidence for why electron has a negative charge • Discuss why plum and pudding model was supported by evidence available at the time.	DCI: *Structure and properties of matter:* each atom has a charged sub-structure consisting of a nucleus, which is made of protons and neutrons, surrounded by electrons. CCC: *Patterns:* Students observe patterns in systems at different scales and cite patterns as empirical evidence for causality in supporting their explanations of phenomena. They recognize classifications or explanations used at one scale may not be useful or need revision using a different scale; thus requiring improved investigations and experiments. SEP: *Developing and using models:* • Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system. • Develop and/or use a model (including mathematical and

				computational) to generate data to support explanations, predict phenomena, analyze systems, and/or solve problems.
3: How do we know what's inside an atom?	• Gold foil (Rutherford) experiment simulation	The pattern observed by Rutherford suggests that atoms are mostly empty space since most positively charged particles (alpha particles) went through the foil undisturbed. Since only a few particles bounced back, it suggests that atoms have small positively charged center that is much smaller in size than the actual atom. Since a positively charged particles deflected, it suggests that there is a strong field around positively charged center of the atom that causes alpha particles to change its path.	Matter is made up of atoms with small positively charged nucleus that is much smaller than the rest of the atom.	DCI: *Structure and properties of matter:* Each atom has a charged sub-structure consisting of a nucleus, which is made of protons and neutrons, surrounded by electrons. CCC: *Patterns:* Students observe patterns in systems at different scales and cite patterns as empirical evidence for causality in supporting their explanations of phenomena. They recognize classifications or explanations used at one scale may not be useful or need revision using a different scale; thus requiring improved investigations and experiments. SEP: *Developing and using models:* • Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system. • Develop and/or use a model (including mathematical and computational) to generate data to support explanations, predict phenomena, analyze systems, and/or solve problems.
4: Where are the electrons?	• Dropping a pencil into the center of a target drawn on a piece of paper to start learning about the concept of probability density • Simulation on predicting random events.	Electrons are best represented as a cloud surrounding the center of the atom (nucleus). This cloud is best modeled as probability density map, with varying probability of finding electron at any given point in space at any given time.	Matter is made up of atoms with small positively charged nucleus that is much smaller than the rest of the atom, and electrons that are best represented as a cloud, or a probability	DCI: *Structure and properties of matter:* Each atom has a charged sub-structure consisting of a nucleus, which is made of protons and neutrons, surrounded by electrons. *CCC: Patterns:* Students observe patterns in systems at different scales and cite patterns as empirical evidence for causality in supporting their explanations of phenomena. They recognize classifications or explanations used at one scale may not be useful or need revision using a different scale; thus requiring improved investigations and experiments. SEP: *Developing and using models:* Develop, revise, and/or use a model based on evidence to illustrate and/or predict the

	• Representing electrons with probability map simulation		density map around the nucleus	relationships between systems or between components of a system.

Investigation 5: How does an object become charged? HS-PS1-1. Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms.				
Activity	**What did we observe?**	**What did we figure out?**	**Model/Explanation**	**NGSS Dimensions**
1: What is the effect of changing the composition of an atom?	• Simulation to study what makes one element different from another • Simulation to show how atoms become charged	• The number of protons determines the type of atom and can affect its charge. • Changing the number of electrons changes the charge of an atom. • There may be different numbers of neutrons in the same type of atom. The number of neutrons does not affect the charge of an atom. • Atoms become charged by transferring electrons via contact from one atom to the other.	Revise model of electrical interactions to include atomic nature of matter, and electron transfer as a mechanism to explain how objects become charged.	DCI*: Structures and Properties of Matter:* Each atom has a charged substructure consisting of a nucleus, which is made of protons and neutrons, surrounded by electrons. The periodic table orders elements horizontally by the number of protons in the atom's nucleus and places those with similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron states. CCC: *Structure and function:* Students investigate systems by examining the properties of different materials, the structures of different components, and their interconnections to reveal a system's function and/or solve a problem. SEP: *Obtaining, evaluating, and communicating ideas:* Communicate scientific and/or technical information or ideas (e.g. about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (i.e., orally, graphically, textually, mathematically).
2: How do objects become charged?	• Looking at the data about how different macro objects interacted with the charged tape to explain resulting interactions using	• Charge is conserved: the number of electrons and protons in the atoms of a given object determines overall charge of the object (equal number of protons and electrons results in no charge, more electrons	• Revised model of electrical interactions includes explaining what neutral and charged mean in terms of number of protons and	DCI: *Structures and Properties of Matter:* Each atom has a charged substructure consisting of a nucleus, which is made of protons and neutrons, surrounded by electrons. The periodic table orders elements horizontally by the number of protons in the atom's nucleus and places those with similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron states. CCC: *Structure and function:* Students investigate systems by examining the

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	ideas related to charge transfer.	result in negative charge, and more protons result in positive charge)	electrons in atoms that make up an object.	properties of different materials, the structures of different components, and their interconnections to reveal a system's function and/or solve a problem. SEP: *Analyzing and interpreting data:* Evaluate the impact of new data on a working explanation and/or model of a proposed process or system.
3: What causes neutral objects and charged objects interact with each other?	• Charged balloon sticking to the neutral wall demo • Neutral atom between two oppositely charged plates simulation. • Balloon and wall simulation	• The electron distribution within an atom can shift in the presence of an electric field to create a separation of charge in which one end of an atom becomes slightly positively charged and the other becomes slightly negatively charged. • Neutral objects contain an equal number of positive and negative charges; charged objects contain an unequal number of positive and negative charges.	In neutral objects, electron cloud shifts away from negatively charged object and towards positively charged object, creating partial charge resulting from shifting of electron density in the atoms of neutral object. These partial charges cause interactions between neutral and charged objects.	DCI*: Structures and Properties of Matter:* Each atom has a charged substructure consisting of a nucleus, which is made of protons and neutrons, surrounded by electrons. The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms CCC: *Cause and effect:* [Students] suggest cause and effect relationships to explain and predict behaviors in complex natural and designed systems. They also propose causal relationships by examining what is known about smaller-scale mechanisms within the system. They recognize changes in systems may have various causes that may not have equal effects. SEP: *Developing and using models:* Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system.
4: Revising our models of charge interactions	• Pie pan on VdG demo (revision) • Franklin Bell demo using coke cans and VdG (revision)	• Revising model of electrical interactions for previously observed phenomena to add microscopic level detail	• Models include electron transfer between objects, attraction between charged and neutral objects, repulsion of like-charged objects. • Atomic structure: include an electron cloud of electron	DCI: *Structures and Properties of Matter:* Each atom has a charged substructure consisting of a nucleus, which is made of protons and neutrons, surrounded by electrons. The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms CCC*: Cause and effect:*[Students] suggest cause and effect relationships to explain and predict behaviors in complex natural and designed systems. They also propose causal relationships by examining what is known about smaller-scale mechanisms within the system. They recognize changes in systems may have various causes that may not have equal effects.

			density (the electron clouds is a region of high probability for finding an electron.)	SEP: *Developing and using models:* Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system.