FIELDS AND INTERACTIONS

Unit Issue: How the characteristics of fields can be incorporated into engineering design solutions.

Anchoring Phenomenon: Objects can be observed to interact with other objects even when they are not in contact with one another. Examples explored include static electricity, the behavior of magnets, and the observation that objects fall toward the earth. Students generate and answer questions such as: How do objects interact at a distance? What is a field? How does a field store energy? How do people use fields to design solutions to problems?

Investigative Phenomena	Driving Questions	Guiding Questions	Activities	PE	Storyline
Gravity, magnetism, electricity, and electromagnetism are used in designed systems.	How do engineers solve problems related to gravity?	What approaches can be used to solve a problem? (Activity 1)	1, 2	ETS1-1 ETS1-2 ETS1-3 ETS1-4	Engineers solve all sorts of problems. For every problem to be solved, there are different tools and scientific concepts that can be used to help design solutions. One scientific concept used in many design solutions is gravity. Gravity can be used when engineering a transportation system on the Moon.
		How do engineers use a design process to solve problems? (Activity 2)			NASA's Apollo missions are an example of a practical application of gravity. Engineers accounted for gravity in their designs of spacecraft that brought astronauts to the Moon. By making use of the engineering design process and understanding the criteria and constraints of the design task, NASA astronauts were able to reach, and return from, the Moon.
When an object is released in the air, it falls to the ground.	What determines the strength of gravitational forces?	How is energy transferred with a transporter set in motion by gravity?(Activity 3)	3, 4	PS3-2 PS2-4	When designing solutions to transportation problems, the amount of energy stored in the system is important to consider. By changing a transporter's mass or height, the energy stored in the system changes. This change is due to gravitational potential energy.
		What determines the amount of gravitational force between objects? (Activity 4)			Scientific investigations to learn more about gravity can be conducted on the two variables that seem to affect gravitational force: mass and distance. Beyond simple classroom investigations, observations of objects interacting gravitationally gives evidence that gravity is a force at a distance. That is, gravitational force is able to affect interacting objects even if those two objects are not touching.

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Magnets are attracted to or repelled by other magnets.	How do magnetic forces work?	How can we visualize a magnetic field? (Activity 5)	5	PS2-5	The ability for objects to interact without being in physical contact is evidence for, and can be explained by, fields. While gravitational fields exist around all objects with mass, there are other types of familiar fields, like magnetic fields. A field, such as a magnetic field, can be mapped using tools that sense a field's direction and/or strength. For instance, a compass placed in a magnetic field will point in the direction of the field at that location.
Gravity, magnetism, electricity, and electromagnetism are used in designed systems.	How can engineers solve problems using magnetism and gravity?	How can magnetic fields be used to design a transporter prototype? (Activity 6)	6	PS2-3 PS2-4 ETS1-1 ETS1-2 ETS1-3 ETS1-4	What happens if an object is experiencing a force at a distance due to more than one field? The object will move in the direction of the stronger force until the two forces are balanced. Balanced forces from magnetic and gravitational fields can be used to design a hovering transporter. Depending on how much mass needs to be moved, the magnetic field needs to be strong enough to balance the gravitational force on the transporter. Designing a hovering transporter includes analyzing data from tests to create new improved solutions.

PHENOMENA, DRIVING QUESTIONS AND SEPUP STORYLINE

FIELDS AND INTERACTIONS (continued)

Investigative Phenomena	Driving Questions	Guiding Questions	Activities	PE	Storyline
Gravity and magnetism both affect objects at a distance.	What are fields?	What factors affect the strength of a field? (Activity 7)	7	PS2-3 PS2-4 PS2-5 PS3-2	While gravitational fields and magnetic fields are similar in that they can exert a force at a distance, they also have some important differences. Magnetic fields exist only around magnetized objects, whereas gravitational fields exist around all objects with mass. Also, gravitational fields are only and always attractive, whereas magnetic fields can be attractive or repulsive depending on the relative orientations of the interacting magnetized objects. An important aspect of fields is that they can store potential energy. An object in a field has potential energy due to its location in that field. If an object changes its location in a field, then the potential energy of the object due to the field has either increased or decreased depending on if energy was transferred to or from that object.

PHENOMENA, DRIVING QUESTIONS AND SEPUP STORYLINE

FIELDS AND INTERACTIONS (continued)

Investigative Phenomena	Driving Questions	Guiding Questions	Activities	PE	Storyline
When a balloon is rubbed on hair, the hair will be attracted to the balloon even as the balloon is pulled away.	What is static electricity? How can we generate more static electricity?	What are the effects of static electricity? (Activity 8)	8, 9, 10	PS2-3 PS2-5 PS3-2	Gravitational and magnetic fields are not the only types of fields. Electric phenomena are due to electric fields. The everyday experience of static electricity demonstrates the properties of an electric field. Objects with static electricity can be attracted to or repelled from other objects due to electric fields.
		What determines the amount and direction of electrostatic force? (Activity 9)			An object becomes charged when there is a difference between the number of positive and negative charges on it. A more highly charged object will have a larger effect on nearby charges. Also, the closer that object gets to nearby charges, the larger effect it will have.
		What effect does an electric charge have on the space around it? (Activity 10)			Electric fields are a result of electric charges. Charges can be either negative or positive. Two electric charges with the same charge will repel each other, whereas two electric charges with opposite charge will attract each other. Like gravity and magnetism, electric fields also store potential energy.
Gravity, magnetism, electricity, and electromagnetism are used in designed systems.	How can engineers solve problems using electric fields?	How can the Moon transporter use an electric field? (Activity 11)	11	PS2-3 PS3-2 ETS1-2 ETS1-3 ETS1-4	Engineers can use electric fields in the hover transporter design in a manner similar to the magnetic hover transporter. Electric charges can be built up on the transporter and track, which provides an electrostatic force that balances the force of gravity. By testing and manipulating the charge on the transporter and track, the transporter's design can be optimized. If the repulsion gets strong enough, charges can actually be forced off of the charged object, causing discharge. This is one of the reasons why electric fields are not as practical as magnetic fields in this application. A field, such as a magnetic field, can be mapped using tools that sense a field's direction and/or strength. For instance, a compass placed in a magnetic field will point in the direction of the field at that location.

PHENOMENA, DRIVING QUESTIONS AND SEPUP STORYLINE

FIELDS AND INTERACTIONS (continued)

Investigative Phenomena	Driving Questions	Guiding Questions	Activities	PE	Storyline
Metals that are not magnetic can be affected by moving magnets, and moving charges can generate magnetic fields.	How are electric fields and magnetic fields related?	What is the relationship between electric and magnetic fields? (Activity 12)	12, 13, 14	PS2-3 PS2-5 ETS1-4	Since electric fields can cause electric charges to move, electric fields can cause charges to move through wires to make electric current. As electric current moves through a wire, a magnetic field is produced around the wire. Likewise, if a magnetic field is moved near a wire, electric charges start to move, creating electric current. This relationship between electric current and magnetism allows for the creation of electromagnets.
		How can an electromagnet be used to design a rescue device? (Activity 13)			Electromagnets create a magnetic field only when there is an electric current flowing. Unlike permanent magnets, electromagnets can have their magnetic field turned on and off. This is a useful property used by engineers for all types of design tasks. A stronger electromagnet can be built by winding coils with a high number of turns of wire per length of coil and/or increasing the current through the wire.
		How do electric and electromagnetic fields work? (Activity 14)			It is because of the relationship between magnetism and electricity that scientists often refer to an "electromagnetic field" instead of the separate magnetic and electric fields. This larger, more-encompassing field interacts with both magnetic and electric fields and shares properties with each. Electromagnetic fields are used in many devices and products that we use every day. In fact, a certain type of transportation, known as magnetic levitation, uses electromagnetism to hover trains above their track and move them at high speeds along the track all while in a gravitational field. Fields, such as electromagnetic and gravitational, are useful in designing a transporter on the Moon where one of the constraints is that combustion cannot be used.

PHENOMENA, DRIVING QUESTIONS AND SEPUP STORYLINE

FIELDS AND INTERACTIONS (continued)

Investigative Phenomena	Driving Questions	Guiding Questions	Activities	PE	Storyline
Gravity, magnetism, electricity, and electromagnetism are used in designed systems.	How can engineers solve problems using electricity, magnetism, and gravity?	Which is the best design for the Moon transporter? (Activity 15)	15	ETS1-2 ETS1-3	To choose the best design from proposed solutions, scientists and engineers systematically compare possible solutions to see how they meet the criteria and constraints of the challenge. It is these systematic processes that allow engineers and scientists to develop, test, and improve solutions before deciding on a final design.