Understand and Draw Fields - Fields and Forces 2 - NGSS Aligned

The Big Question: Can fields affect people? Do people have fields?

Student Learning Goals:

1. Write a hypothesis about each item below, and devise a way to test each hypothesis.
    a. How field strength varies with source strength.
    b. How field strength varies due to the test object.
2. Draw and describe the electric field around one or two charges, and the magnetic field around a magnet.
3. Draw the force vector on a test object in a field, given a drawing of a field.
4. Extend your understanding of electric and magnetic fields to gravitational fields.

Specific NGSS related learning goals for this lesson (lesson level performance expectations)

1. Make, explain, and defend drawings or other models of E-field around one or two charges, B-field around a magnet, and gravitational field around a planet.
2. Predict the effects of forces on charged particles or masses in the fields and what happens to the forces when the fields change. (Demonstrate predictions on drawings)
3. Make and test hypotheses to specify what happens to field strength when mass/charge/ magnetic strength of the cause and of the victim are varied. (Field does not change when victim properties are changed).

Evidence of Understanding (the student will be able to):

1. Draw and explain the gravitational field, electric field, or magnetic field around a planet, one or two charges, and a magnet.
2. Draw/discuss your prediction of the direction and relative magnitude of force on positive and negative charges, masses, or the N pole of a compass at various positions in a field, given a drawing of the field (or drawing from above).
3. Write a hypothesis and devise a way to use the sim to test it, about how field strength varies with mass, charge, or magnet strength of victim and cause.
4. Define “field”.

NGSS goals related to performance expectations HS-PS2-4, HS-PS2-5, HS-PS3-2, and HS-PS3-5
DCI: (Electric and gravitational) models describe and predict the effects of gravitational and electrostatic forces between distant objects. Emphasis is on conceptual descriptions of gravitational and electric fields.(HS-PS2-4)
Practices: Develop and use Models, Engaging in Argument from Evidence
Crosscutting Concepts: Energy and Matter
CCSS-ELA/Literacy WHST.11-12.7 - Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.
CCSS-Mathematics MP.2 - Reason abstractly ~~and quantitatively~~.

Background - for a high school Physics class

Students will have finished Force and Fields 1 with PhET sim Electric Field Hockey.
Students can

- explain the mystery of “action at a distance” (how can a force be applied by an object when it is not touching the other object),
- define the meaning of an electric field,
- predict the force on a charged object in an electric field when the direction of an electric field is known at the location of the object.

In this lesson students will

- gather evidence to make arguments about the cause of fields,
- will make electric, magnetic field drawings,
- use what they have learned to make a drawing of a gravitational field around a planet,
- and predict the effect of the field on a satellite.

Pre-Lesson Introduction and Exploration

1. Opening statement - connect to prior learning. Example: "We saw that there is an electric field around charged objects that permeates space and causes forces on other charged objects. Today we will look at the cause of fields, the connection between electric, magnetic, and gravitational fields, and we will develop drawings that represent the strength and direction of these fields. (Write questions on the that address the learning goals.) The big idea question might be **Can fields affect people? Do people have fields?**
2. Students explore the simulation Magnets and Electromagnets - about 3 minutes.
3. Students share what they found. Lead into the topic of how to draw fields.
    a. How did Electric Field Hockey (EFH) show the direction of the field?
    b. How did EFH show the strength of the field?
    c. How does Magnets and Electromagnets (M&E) show the direction of the field? (there may be some confusion about the direction - red represents north in this simulation)
    d. How does M&E show the strength of the magnetic field?
    e. (Possible question - why didn't this sim use arrows?)
4. Demonstrate the "conventional" way to draw fields by hand (with continuous lines from source charges to infinity, and arrowheads). No need to dwell on the directions of the fields (toward negative, toward south outside a magnet) because students will learn this as they do the activity.

Student Activity - Key concepts

Part A-i. The effect of source charges, bar magnets, and electromagnets on the field

Electric Field
- Field points toward negative, away from positive (the direction a positive is pushed)
- Field gets weaker with distance ($1/r^2$)
- The stronger the source charge, the stronger the field at a given distance (put a bunch of like charges close together and observe how the field darkens)

Magnetic Field
- Field points from north to south (the direction a N pole is pushed)
- Field gets weaker with distance ($1/r^2$)
- The stronger the magnet, the stronger the field at a given distance (use electromagnet)

Part A-ii. The effect of the test object (puck, compass) on the field

Puck has no effect on the field. It is a "test charge" with a very small charge and a "compass" with a very small magnet. Observe by putting the puck in the E-field screen with no source object (there is no field). Observe by moving the compass around the bar or electromagnet (there is no change in the field).

Part B. Drawing field diagrams

Circulate and check student drawings to make sure they are using arrowheads to show direction of the fields, and to make sure the rest of the details are correct.

Part C. Test your understanding of the relationship between forces and fields.

Check to make sure students show the charge on the charged test object, and the labels N and S on the compass magnet.

Part D. Gravitational fields

Similarities:
- weaker with distance ($1/r^2$)
- field lines indicate direction of force
- the bigger the source the stronger the field at a given distance

Differences:

- force is on a mass, not charge or magnet
- inward only and (from prior knowledge) g-field is relatively weak.

Post-Lesson

Students share their findings. Check for misunderstandings.
Practice indicating force/field given drawings or situations.
Ask the “big idea” questions: Do fields affect people? Do people have fields?
Evaluation