

The Big Question: Two like charges are placed close together. They gain kinetic energy as they fly apart. Where did the energy come from?

Student Learning Goals:

1. Investigate what causes the kinetic energy of an object to change when it is placed in a field.
2. Connect conservation of energy concepts to changes in the kinetic and potential energy of an object in a field.
3. Use screenshots, drawings, and words to defend and communicate conclusions about the relationship between energy and fields.

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

Investigate, draw conclusions, and defend conclusions about energy and fields including that energy due to position can be thought of as stored in fields, and that the energy stored in fields changes when two interacting objects in the field change relative position.

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

1. Investigate and draw conclusions the relationship between the changes in kinetic and potential energy due to relative positions of an object in a field.
2. Express and defend conclusions using conservation of energy concepts with words, drawings, and screenshots from the simulation.

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 and 2, with PhET simulations Electric Field Hockey and Magnets and Electromagnets.

Required student background understanding

- Conservation of energy, with an understanding that potential energy is the energy of relative position and kinetic energy is the energy of motion.
- When work is done on a system, either the potential energy or the kinetic energy, or both, of the system increases.
- Work is done when a force is applied over a distance.

From activity 1, 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.

From activity 2, students can

- write a hypothesis about how field strength varies with source strength but not with strength of the test object.
- draw and describe the electric field around one or two charges, the magnetic field around a magnet, and the gravitational field around a mass.
- draw the force vectors on a test objects in a field, given a drawing of a field.

In this lesson students will

- review conservation of energy in the context of an object in a field
- investigate changes in energy of objects in a field
- draw conclusions about where potential energy is stored (in fields)
- communicate and justify their conclusions with words, drawings, and screenshot evidence.

Pre-Lesson Introduction and Exploration

Opening statement - connect to prior learning. Example: "We saw that charges are surrounded by electric fields, magnets are surrounded by magnetic fields, and masses are surrounded by gravitational fields. The fields enable objects to apply forces to other objects without touching them. Today we will look at the relationship of energy and fields.

- a. Briefly review conservation of energy in the context of an object in a field gaining kinetic energy. Lead to the questions for the lesson, below.
- b. Questions for the lesson (write on the board): "**Two like charges are placed close together. They gain kinetic energy as they fly apart. Where did the energy come from?**"

Brief Outline of the Student Activity

1. Small group discussions and self-directed explorations, with the goal of developing an answer to the question above. Have computers available so students can use the simulations.
2. Students use screenshots, drawings, and words to defend and communicate conclusions about potential energy and fields.
3. Groups meet with another group to share explanations, reasoning, and evidence following the

Guidelines for sharing and discussing:

- Listen to one group's explanation and reasoning without speaking.
 - Ask clarifying questions, as needed, to understand their ideas.
 - Give warm (positive) feedback - what do you agree with, what do you find interesting (positive only), etc.
 - Give cool (constructive) feedback - what do you find confusing, conflicting, or perhaps disagree with.
4. Meet with original group again, revise explanations, reasoning, and evidence as needed. Students will need teacher initials in the "Official Initial Box" as evidence that their explanation is complete.
 5. Original group makes a presentation-worthy document or poster using words and drawings and/or screenshots to answer the pre-lesson question with reasoning and evidence.

Key Concepts from Student Activity - Electric Field Hockey & Magnets and Electromagnets sims

- An object placed in a field will gain kinetic energy (if the object is the type that interacts with the field).
- The kinetic energy must be transferred from another form of energy. Nothing else is moving in the field, so it must be a form of potential energy.
- Where is the potential energy stored? When you do work on the system (move like charges closer together, for example), the potential energy increases and the field changes.
- Potential energy must be stored in the field itself.

Post-Lesson

Class discussion leading to consensus that potential energy is stored in fields. (We don't know the mechanism, we just know that energy is stored in the fields.)

Fields and Energy - Fields and Forces 3 - NGSS Aligned

Answer the question: "Two like charges are placed close together. They gain kinetic energy as they fly apart. Where did the energy come from?"
Check for misunderstandings and evaluate.