Before you is a plastic surface and a contour map each representing the electric potential. A 1-*cm* height difference corresponds to an electric potential difference of 1 *V*.

Consider the Motion of a Positive Charge: If you were to place a positively charged particle at rest at the blue square, which way do you expect the particle to move?

- What direction is the force on the charged particle?
- Does the charged particle move toward higher or lower electric potential?
- Does the electric potential energy increase, decrease, or stay the same?

> Instructor's guide **Goal:** This question is trying to get students to articulate a resolution to force and energy descriptions of this situation.
>
> **Answer:** Moves toward the negative plate, which is toward lower electric potential. Potential energy decreases so, yes, they agree.

Consider the Motion of a Negative Charge: If you were to place a negatively charged particle at rest at the blue square, which way do you expect the negative charged particle to move?

- What direction is the force on the charged particle?
- Does the charged particle move toward higher or lower electric potential?
- Does the electric potential energy of the system increase, decrease, or stay the same?

> Instructor's guide **Answer:** Moves toward the positive plate, which is toward higher electric potential. Potential energy decreases, so, yes, they agree because potential is independent of the sign of the charge but potential energy is not.
>
> **Student Ideas:** Students might conflate potential with potential energy and either think that both will increase or both will decrease. If they think it will increase, ask them to think about energy conservation (the potential energy decreases if the kinetic energy increases and energy is conserved). If they think they will both decrease, remind students that potential doesn't depend on the sign of the test charge, so the surface should not rotate between this case and the previous case.

Consider the Electric Field at the Blue Square: Draw a vector on the contour map to indicate $\vec{E}$ at the blue square.

- Explain your reasoning.
- Does your answer depend on the sign of the charge?

> Instructor's guide **Answer:** It should not.

- How is the vector oriented with respect to the contour lines?

> Instructor's guide **Answer:** It is perpendicular.

> Instructor's guide **Student Ideas:** Students might know that the electric field should be perpendicular to the equipotential lines. If they use this reasoning, try to get them to reconcile it with a superposition approach.

Consider the Electric Field at Several Points: Draw vectors at several additional points to represent $\vec{E}$, making sure the lengths of the vectors are qualitatively accurate. Choose points near the middle and edges of the map.

- How do the electric field vectors near the middle compare with the vectors near the edge of the map?

Instructor's guide **Answer:** the electric field near the edge will be pointing is different directions (not parallel to each other) and will be shorter.

- How are the electric field vectors related to the equipotential lines?

Instructor's guide **Answer:** should be perpendicular. This may not be easy to see if students have not been careful about how they've drawn the vectors.

Instructor's guide **Student Ideas:** Students might know that the electric field should be perpendicular to the equipotential lines. If they use this reasoning, try to get them to reconcile it with a superposition approach.

Instructor's guide

SUMMARY PAGE

What Students Learn:

- Potential and potential energy are different. The value of potential is independent of the sign of charge of the test particle.
- Force and energy are both ways to understand how charged objects interact.
- Review that electric field and electric potential are related to force and potential energy.
- Electric field vectors are perpendicular to equipotential surfaces and are short if the curves are closely spaced.

Time Estimate: 20 minutes

Equipment:

- Yellow plastic surface (1 per group)
- Contour map for parallel plate capacitor with plastic sleeve (1 per group)
- Big whiteboard (1 per group)
- Dry-erase markers and erasers (1 each per student)
- Student handout (1 per student)

Introduction:

- Students need to understand that the surface represents the electric potential in the center of a parallel plate capacitor. Try doing the activity *Electric Potential of Two Charged Plates* before this activity.
- Students should know that
  1. objects with like charge repel and opposite charge attract,
  2. object tend to move toward lower energy configurations
  3. The potential energy of a charged particle is related to its charge: $U = qV$
  4. The force on a charged particle is related to its charge: $\vec{F} = q\vec{E}$

Whole Class Discussion / Wrap Up:

- Have students articulate their reasoning how the negative charge will move. Make sure force and energy reasoning are articulated by students.
- Have students propose relations between the electric field vectors they've draw and the equipotential surfaces. The correct orientation (perpendicular) may be difficult to perceive if the students haven't draw the arrows carefully. The relation between the strength/spacing may be easier for students to see.