Name: ________________________

Charged Sphere

*Each prompt will have the goal of the prompt and additional questions you may want to ask each group (or the whole class) as they work. The horizontal direction of the surface represents distance, **r** in this case. The surface of the sphere is marked by an indent in the surface near the lowest corner. The height of the surface corresponds to the value of electric potential. Read the introduction below to the class before beginning. In the last 5 minutes of class, pass out the Post-Activity Evaluation.*
Important things to note (you may choose to put this on the board): The surface and the contour map represent the SAME system and the SAME variables (distance and electric potental). Electric potential goes to 0 when r goes to infinity.

Your group has a plastic surface and a contour map that represent the electric potential due to a charged sphere as a function of position. The electric potential is zero infinitely far away from the sphere. Solve the following problems together and discuss the results.

You are employed by an electronics company called Crabapple Technologies. Crabapple wants to put a small charged nanoprobe at the blue circle.

(1) If the nanoprobe moves further away from the sphere, how will the electric potential change? What if the nanoprobe moves closer to the sphere?

Goal: General trend of electric potential. How does electric potential change with respect to distance?

Additional Questions: Prompt students to look at the continuous change of the potential (i.e. not just picking one point and comparing the two values) or have them choose several points to compare.

(2) Identify other points on the surface where the electric potential is the same as the potential at the blue circle and draw a line to connect them. Do the same for the orange star and the green square.
 (a) Align your surface with the contour map. How are you making your alignment?
 (b) How could the nanoprobe move so that the electric potential remains constant?

Goal: Introducing contour lines - places where the value of potential is the same. What do contour lines represent? Explicit combination of representations.

Guide: How can you tell the value of potential? What feature of the surface represents potential? Find one spot where the potential is the same as at the blue circle and draw a dot. Do this again for several other points and connect them with a smooth line. What do these lines mean? Why are they drawn on the map? What information do the contour lines give you? How could you relate this to the lines you just drew on your surface? What main features could you use to align the surface to the map?

(3) Sketch a graph of the potential (V) vs. distance from the center of the sphere (r). Remember to label your axes.
 (a) Does your graph match your answers to (1)? If not, reconcile any differences.
 (b) Why is it reasonable to represent the information from the surface in a graph with only 2 axes?

Goal: Visualize the function V(r)

Guide: What are you graphing? What axes should you plot? What will the axes look like? Where is potential zero? How does potential change with respect to distance? How could you represent that on your graph? Remember that height represents the value of electric potential.

Additional Questions/Comments: Note where students are putting V=0. Ask them to label it on their graph. If students have trouble with the graph inside of the sphere, ask them "do you need to think about inside the sphere if we are talking about a probe outside the sphere?" If they want to graph within the sphere, they can use the surface to determine what the graph should look like.

(4) Indicate the direction of the field at the blue circle on the contour map. Explain your reasoning.

Goal: Start the students with something intuitive. They should know Coulomb force points along the line between charged objects, and can use that to determine electric field direction. The students will have to infer that the sphere is negatively charged.

Guide: Locate the point on the contour map. What direction is the Coulomb force in? What is the qualitative magnitude (i.e. is the force very very small? very, very big? somewhere in between?)? Remember that this is a sketch of the vector, so the magnitude does not need to be exact.

(5) Locate a point where you would expect the electric field to be larger. How do you know it's larger?

Goal: Compare field at two different points. Begin to connect field to change in electric potential.

Guide: In what direction is the field at the blue circle? Does the field change depending on the position of the nanoprobe? Does the electric field get smaller or larger as the nanoprobe moves closer to the sphere?

Additional questions: In what way is the change in potential different at this point?

Note: Students may locate a point on one representation (graph, contour map, surface) - have them locate the point on all representations.

(6) Is the rate of change of electric potential with respect to $\boldsymbol{r}$ positive, negative, or zero?

(7) Compare $\frac{dV}{dr}$ at the two points from (4) and (5). Which one has a larger magnitude?

Goal: Introduction to relating potential to field. We already talked about the field, now we will examine the change in potential energy. Compare $\frac{dV}{dr}$ and begin to make a connection between magnitude of field and magnitude of $\frac{dV}{dr}$.

Guide: Rate of change is represented by the slope.

(8) Sketch a graph of the electric field vs. distance from the center of the charged sphere. Remember to label your axes.

Goal: Visualize the function E(r)

Guide: What are you graphing? What axes should you plot? How does field change with respect to distance? How could you represent that on your graph? Is field positive or negative? Note that if students make the field positive, they are plotting the magnitude of the field. The component of the field is negative since it points opposite to increasing $\boldsymbol{r}$.

(9) The Crabapple employee handbook states:

> There is a relationship between electric potential and electric field; field is the negative gradient of potential. $\vec{E}(\vec{r}) = -\vec{\nabla}V(\vec{r})$

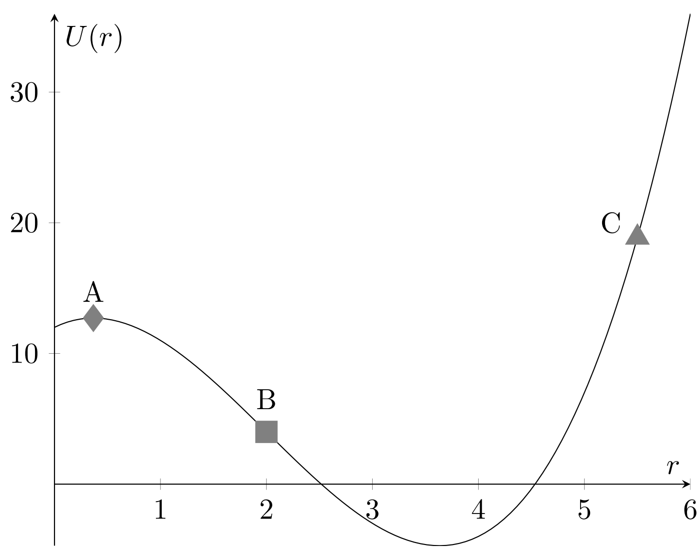
Do you agree? Support your answer with evidence from this activity.

Goal: Develop a relationship between potential and field based on knowledge gained in this activity.

Guide: Direct students to their answers from (4), (5), (6). Does the magnitude of the field seem to change w.r.t. a change in potential? Which direction is force in?

Pre-Activity
Write down things you know about electric potential.

This is a graph of potential energy as a function of distance with appropriate units. Rank the magnitude of the force at the following points (diamond, square, and triangle) on the graph from greatest to least.



Write at least one question you have about electric potential.

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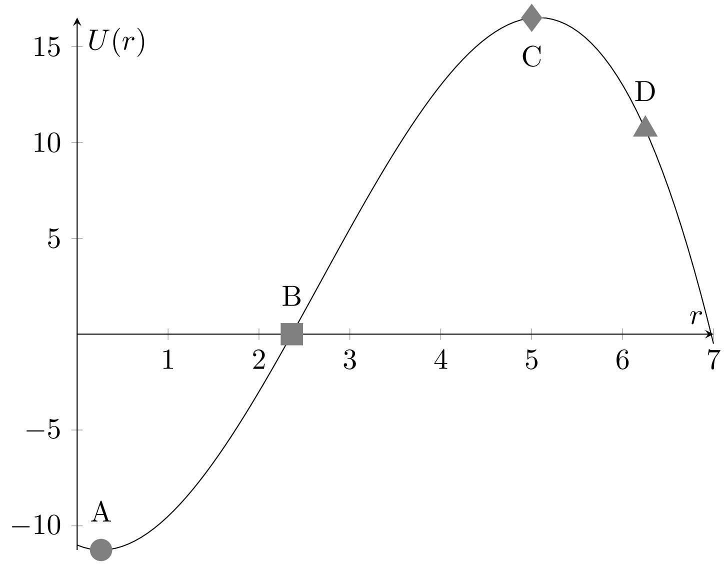
Activity Evaluation

Write something specific you learned from today's activity.

This is a graph of potential energy as a function of distance. Rank the force at the following points (circle, square, diamond, and triangle) on the graph from greatest to least.



What questions do you still have? What new questions came up?