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| **Lesson Title** | Electric field mapping in 3D |
| **Length of Lesson** | 2 days |
| **Created By** | Edward Leggett, William Funderburk |
| **Subject** | Physics |
| **Grade Level** | 11-12 |
| **State Standards** | Physics 1d; 5a |
| **DOK Level** | 4 |
| **DOK Application** | Design, Analyze, Create |
| **National Standards** | 9-12: B (physical); |
| **Graduate Research Element** | 3D data mapping |

**Student Learning Goal:**
Physics: 1. Apply inquiry-based and problem-solving processes and skills to scientific Investigations: (d) Organize data to construct graphs (e.g., plotting points, labeling x-and y-axis, creating appropriate titles and legends for circle, bar, and line graphs) draw conclusions and make inferences.

5. Apply an understanding of magnetism, electric fields, and electricity: (a) Analyze and explain the relationship between electricity and magnetism - Electric field, electric potential, current, voltage, and resistance as related
to Ohm's Law.

National Science Education Standards of Content 9-12
B (Physical): Motions and Forces: The electric force is a universal force that exists between any two charged objects. Opposite charges attract, while like charges repel. The strength of the force is proportional to the charges, and, as with gravitation, inversely proportional to the square of the distance between them.

**Materials Needed (supplies, hand-outs, resources):** Aquarium, large 12 volt battery, distilled water, a small amount of powdered coffee creamer, multi-meter, single core wire, copper strips, and a computer with a computer algebra system installed (i.e. Mathematica, MAPLE, etc.)

**Lesson Performance Task/Assessment:** In this lesson, students will design an experiment for taking voltage measurements in a 3 dimensional box. They will fit their measured data to a 3 dimensional function. The electric field will be found by taking the gradient of the fitted data. Finally, students will visualize their data by creating a vector field map and a map of equipotential surfaces.

**Lesson Relevance to Performance Task and Students:**
This lab teaches students to measure data in 3 dimensions, fit a 3 dimensional function, take the gradient of a function using a computer algebra system, and visualize data in 3

dimensions. These skills can be used to manipulate a wide variety of physical data from a number of fields.

**Anticipatory Set/Capture Interest:**
The teacher will show a 3D vector field map created from the teacher's data.

**Guided Practice:**
Day 1: The teacher will challenge students to accurately measure the voltage on a grid of points inside an aquarium field with water. The teacher will introduce various supplies and possible uses, such as: 1) using graph paper and 2 different color lasers to locate a point in space within the aquarium, 2) the need for a substance to disperse light in the water in order to see the lasers (coffee creamer works well, careful not to use too much), or 3) the need to use distilled water to limit conduction.

Day 2: The teacher will demonstrate the needed functions to accomplish 3D curve fitting and graphing.

**Independent Practice:**
Day 1: Students will design an apparatus to measure the voltage along a 3D grid in an aquarium that contains 2 flat copper electrical leads.

Day 2: Students will fit a 3D function to their voltage data from the previous week. They will then determine the electric field by taking the gradient of this fitted function. They will then produce a 3D vector field plot of the electric field.

**Remediation and/or Enrichment:**
R: individual IEP; partner help throughout lesson

E:

**Check(s) for Understanding:**
* How does our voltage measurement give us the E-field?
* Why don't we just measure the E-field directly?
*Why did we need to perform a 3D fit to the data?
*Where would an electron go if it were placed inside of the aquarium at an arbitrary point?

**Closure:**
Students will show their field maps on a projector screen, and discuss the reasonableness of their measured electric field.

**Possible Alternate Subject Integrations:**

*Math – 3D curve fitting is an advanced numerical technique. Also, the idea of a gradient leads into 3D vector calculus.

**Teacher Notes:**