Lesson Title	Mine Field: 2D Vectors
Length of Lesson	1.5 hours
Created By	Justin Warren
Subject	Physics
Grade Level	11-12
State Standards	Physics: 2 a
DOK Level	DOK 3
DOK Application	Use concepts to solve non-routine problems
National Standards	9-12: A
Graduate Research Element	Variables in engineering problems are routinely represented by vectors and higher order tensors

Student Learning Goal:

Students will investigate vector components and vector addition through a physical and interactive lab.

Physics: 2. Develop an understanding of concepts related to forces and motion: a) Use inquiry to investigate and develop an understanding of the kinematics and dynamics of physical bodies

National Science Education Standards of Content 9-12

A (Science as Inquiry): Scientists rely on technology to enhance the gathering and manipulation of data. New techniques and tool provide new evidence to guide inquiry and new methods to gather data, thereby contributing to the advance of science. The accuracy and precision of the data, and therefore the quality of the exploration, depends on the technology used.

Materials Needed (supplies, hand-outs, resources):

Small orange road cones (three for each group of three students), one cardboard box of any size, trundle wheels (one for each groups but could be shared), smart phone with a compass app (handheld compass would also work), access to a large area such as an outdoor field or basketball court, yellow caution tape, three stakes

Lesson Performance Task/Assessment:

The instructor will use the three stakes and yellow caution tape to construct a 2D coordinate system on the large open area (a stake at the origin and one at the ends of the axes with caution tape connecting them). The instructor will then randomly place the small orange cones in an even distribution throughout the large open area with the cardboard box placed at the center of the area. Markers will be placed at evenly spaced intervals around the perimeter to represent the starting positions for the student groups. The cones represent mines, and the cardboard box represents the base camp. Figure 1 shows what this might look like. Notice that the traditional Cartesian x-y coordinate system has been replaced by the compass headings so that the i and j vector components will be replaced by north and east components.

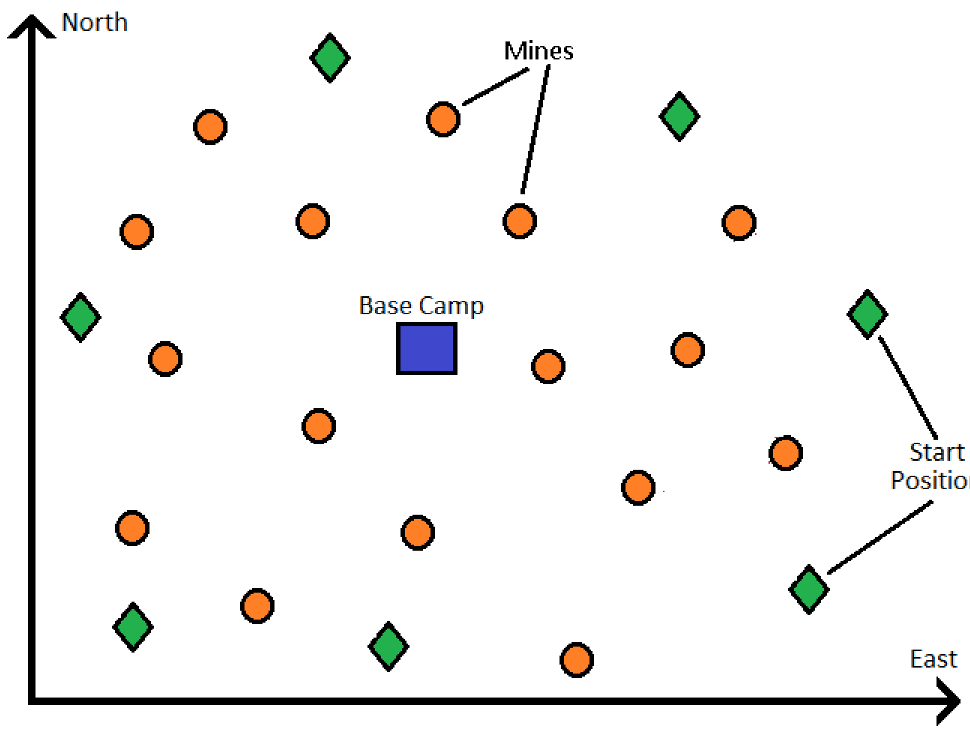

Figure 1. Mine field and base camp

The three person student groups will each begin at any one of the starting positions located along the perimeter of the mine field. Their goal is to make their way to the base camp, but they'll have to get through the mines first. Each group will be responsible for disabling three mines before they can proceed to base camp. "Disabling" a mine simply means turning the cone over. Just for fun, small pieces of candy could be placed under the cones.

While progressing toward the base camp, the students will be responsible for determining four position vectors:

1. from the starting position to the first mine (r_1)
2. from the first mine to the second (r_2)
3. from the second mine to the third (r_3)
4. and from the third min to the base camp (r_4).

Each of these position vectors will be made of two component parts: east and north. Note that these could be negative numbers (negative easy would correspond to walking west). An example of these can be seen in Figure 3. The students can choose any mine that hasn't been disabled.

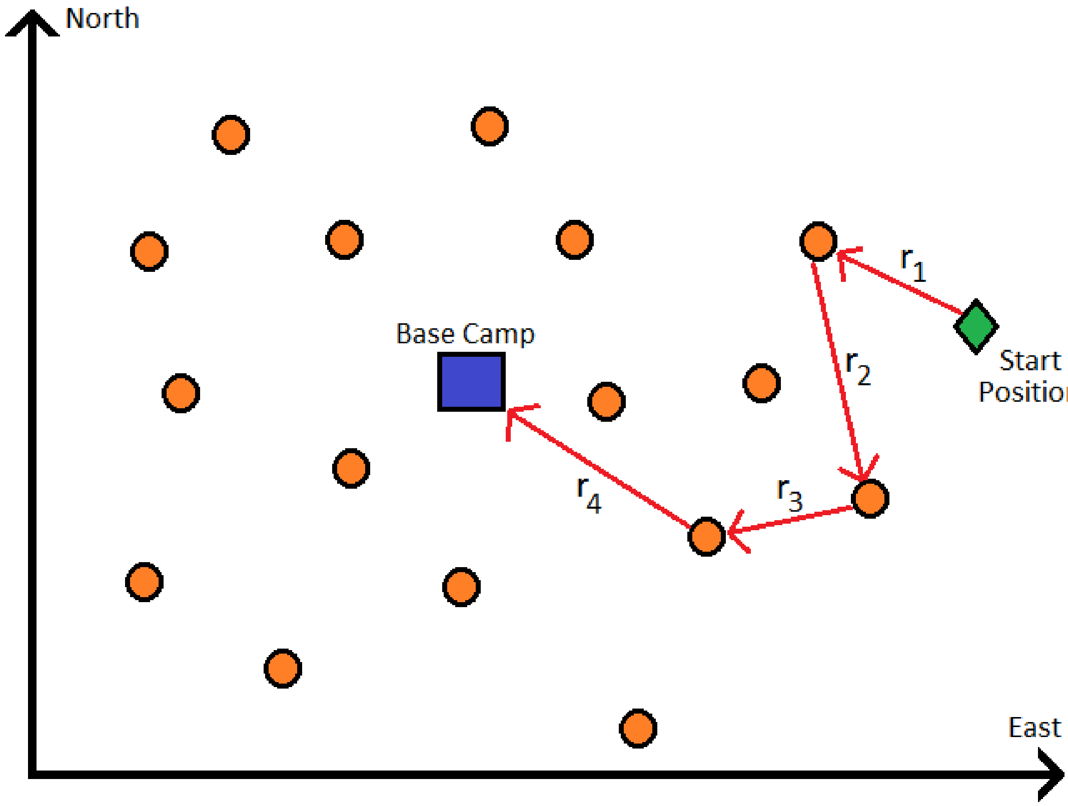

Figure 3. Position vectors to be determined

To determine the position vectors, the students will count the number of paces in the north and east directions using their compasses as an aid to walk only in the direction of the compass headings. Remember, walking in the south or west directions will count as negative components. A sample of pace data can be seen in Figure 4. Only one student from each group will be in charge of pacing the distances so that the average stride length is kept constant.

From	To	Paces East	Paces North
Start Position	Mine 1	3	10
Mine 1	Mine 2	11.5	2
Mine 2	Mine 3	-1	-10
Mine 3	Base Camp	-5	4.5

Figure 4. Sample recorded pace data

The students will then use a trundle wheel to measure the distance from their particular starting position to the base camp. This value will be compared with the value they will calculate later using vector addition. Also, the pacing member of the group will walk ten paces while another member measures this distance with the trundle wheel. Then the distance can be divided by the number of steps to determine an average distance per step.

The students will now go back to the classroom to do calculations. The four position vectors will be constructed from the pacing data. The position vectors for the data in Figure 4 can be seen in Figure 5.

From	To	Position Vector
Start Position	Mine 1	r1 = 3(east) + 10(north)
Mine 1	Mine 2	r2 = 11.5(east) + 2(north)
Mine 2	Mine 3	r3 = -1(east) - 10(north)
Mine 3	Base Camp	r4 = -5(east) + 4.5(north)

Figure 5. Sample position vectors

The students will use vector addition to sum their four position vectors to get a position vector from their starting position to the base camp. This entails algebraically adding all of the east components and north components separately. They can then determine the magnitude of this vector (the square root of the sum of its components squared), convert it from paces to meters (using the average length of the pacer's stride), and compare the resulting value with the distance they measured with the trundle wheel. The two values should be reasonably near each other.

Lesson Relevance to Performance Task and Students:
The student will become familiar with vector components, vector addition, and determining the magnitude of vectors.

Anticipatory Set/Capture Interest:
Hold a fake briefing at the beginning of classes similar to a military unit where the instructor could make up a story line such as: An unmanned aerial vehicle has determined the position of enemy mines in the vicinity of the brigade' base camp. Each squad will be responsible for disabling three mines in order to clear the field and reach the base camp. Any spoils of war such as candy found when disabling mines are to be taken as prize by the squads.

Guided Practice:
The instructor will show the figures above and describe the objectives of the lab.

Independent Practice:
After the mission briefing, the students will proceed to the mine field to perform the lab on their own. The instructor will be present both on the mine field and back in the classroom to offer guidance.

Remediation and/or Enrichment:
Remediation: Individual IEP. It is expected that the relatively simple procedure and relationships involved in this lab will require a very limited amount of remediation if any.

The enrichment activity will be calculating the unit vectors for each of the position vectors.

Check(s) for Understanding:
The student will be required to determine the position vector between two points on a coordinate plane during a 60 second quiz at the beginning of the next class meeting

Closure:
The usefulness of breaking vectors into components when performing vector algebra will be emphasized. It will be noted that scalars and vectors are really just special cases of what is called a tensor, a scalar being a zeroth order tensor and a vector being a first order tensor. Tensors in general are mathematical ways to describe physical quantities, and I use them constantly when performing calculations for my research.

Here are some questions to ask the students to further their understanding of vectors:

- How would you have incorporated altitude into your position vectors?
- Why do you think breaking vectors into components is such a powerful tool for engineers and scientists?
- What sort of physical quantities can you think of that would be represented by vectors?

Possible Alternate Subject Integrations:
The idea of vectors and vector algebra could easily fit well in a mathematics course.

Teacher Notes:
Below are the pictures of a sample problem that was worked on the board during the lab. The values match the sample data used above.