**Experiment 4**

**Vector Addition Using Graph Paper, Simulation, and Math**

Equipment Needed: 4 sheets of graph paper (either 4 squares per inch, or 5 squares per inch), 12-inch ruler, protractor, and pencil.

If you don’t have a protractor available, search for a free image of a protractor online, print it (choose an appropriate size) and cut it out to use.

**Scaling:**

There are many physical quantities that are considered vectors. We will imagine that the vectors being used in this experiment are velocity vectors. Units will be in meters/second. Each square will be considered 1 meter/second wide, and 1 meter/second tall.

**Quadrants:**

Quadrant I: 0° to 90° Quadrant II: 90° to 180°

Quadrant III: 180° to 270° Quadrant IV: 270° to 360°

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|  |  |  |  |  |  |  |  |  |  | Quadrant I  +X +Y  Quadrant II  -X +Y  Quadrant III  -X -Y  Quadrant IV  +X -Y  +X  -X  +Y  -Y |  |  |  |  |  |  |  |  |  |
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**Methods:**

In this experiment you will use three different methods to determine the components of a single vector, and the Resultant of two and three vectors. These methods are: Graphical, Simulated, and Mathematical.

**Graphical:**

Graphical involves using graph paper, protractor, ruler, and pencil. Each graphical method (there are 4 in this experiment) will need to be either scanned as a PDF file, or photo taken using your cell phone, to be included in your report turned in to Drop Box.

**Simulated:**

You will use the simulation called “Vector Addition” on the website: phet.colorado.edu to answer questions pertaining to each of the following parts (1 through 4), placing your answers in the appropriate boxes in the included Excel spread sheet worksheet.

**Mathematical:**

You will use Trigonometric math functions to determine what is being asked for (components of a vector, resultant of two and three vectors), placing these answers in the appropriate boxes on the Excel worksheet.

**Part 1:**

**Components of a Single Vector (20 meters/second at 30°)**

**Graphical:** Draw, in the middle of your graph sheet, a box which is 30 squares by 30 squares. This will be considered a graph of only Quadrant I. Mark the lower left corner of the box as the origin and draw along the bottom the +X-axis, and along the right-hand side the +Y-axis.

Using a protractor, measure out an angle of 30° from the +X-axis, centering the protractor with the origin of your graph, and make a small mark. Count out 20 squares, either horizontally or vertically, and measure this length with your ruler. Angle the ruler such that the zero of the ruler coincides with the origin of your graph and angle the ruler so that it also aligns with the mark you made for 30°. Strike a line with your pencil, along the edge of your ruler, equal to the length you measured for 20 squares. This line will represent the vector equal to 20 meters/second at an angle of 30°.

+ X

+ Y

30°

To **graphically** determine what the X-component and what the Y-component are, run lines from the tip of the vector to each of the X- and Y-axes. Estimate where these lines intersect these axes and write your answers on the Excel worksheet.

Use the **PhET simulation** (Vector Addition) to draw this same vector and determine the X- and Y-components. Once you have opened the simulation, choose “Lab” to determine these components. Near the bottom right-hand corner of the screen you will have the choice of either a blue vector, or a pink vector. Choose the pink vector. This one allows you to set the length and angle of your vector. A box with a green vector and a pink vector will be made available. You will need to “click and drag” a pink vector over to the graph, placing the tail of the vector at the origin. You can then place the cursor onto the head of the vector and “click and drag” the length and angle of the vector. Change it so that it reads at the top of the page a vector of 20.0 and an angle of 30.0. You will then see what the magnitudes of the X- and Y-components. Write these down on the Excel worksheet.

**Mathematically**, use the sine and cosine functions appropriately to determine the X- and Y-components of this vector.

**Part 2:**

**Components of a Vector (20 meters/second at -50°)**

Repeat the process for Part 1, except you are now drawing Quadrant IV, and the angle is -50° from the +X-axis.

**Part 3:**

**Resultant of Two Vectors Added Together**

**Graphical**

On your third graph sheet you will place the origin at the center of the paper, drawing the X- and Y-axes correspondingly. Draw two vectors, , and , such that vector has a magnitude of 12 meters/second and an angle of 25°; vector has a magnitude of 15 meters/second and an angle of 170°.

This graphical method relies on completing a drawing of a parallelogram, of which vectors and make up two sides of the parallelogram.

Once you have completed the parallelogram using your ruler, draw in the Resultant vector, , similar to how it is shown in the above illustration. Yours will be slightly different than the one in the illustration. Use your ruler to measure the length of the Resultant vector. Then see how many blocks fit in this measurement (include fractions of a block). It is the number of blocks which will give the magnitude of your Resultant vector in meters/second. Use your protractor to measure the angle from the +X-axis. Write both the magnitude and the angle of the Resultant vector into the corresponding boxes on the Excel worksheet.

**Simulation**

Again, using the pink vectors in the “Lab” section, place two vectors representing and , with the appropriate lengths and angles. Then, by clicking on “Sum” you will get the Resultant vector. Record the values for the magnitude and angle onto the Excel worksheet.

**Mathematical**

In this case you will do your calculations on the Excel worksheet. Determine the X- and Y-components using Trigonometric functions (sine and cosine) for both vectors and . Combine the X-components together to determine , and combine the Y-components together to determine . From these, determine the magnitude and the angle of the Resultant vector. **Don’t forget, Excel needs to have the angles converted into radians for the Trigonometric functions to properly work**.

**Part 4**

**Resultant of 3 Vectors Added Together**

**Graphical**

Since you are working with 3 vectors it will be easier to combine the 3 vectors by using a “tail to head” method.

As you can see, vector is drawn, starting from the origin. From the head of vector , treating it as a temporary origin, vector is drawn. Vector is then drawn from the head of vector . The Resultant is drawn from the original origin to where the final vector points.

You will use the following three vectors:

= 14 m/s at -15°

= 20 m/s at 135°

= 15 m/s at 250°

**Simulation**

Similar to part 3, place the three vectors onto the graph and click on “Sum” to determine the Resultant.

**Mathematical**

Similar to part 3, use the Trigonometric functions to fine the X-components and the Y-components of each of the three vectors. Then, determine the magnitude and angle of the Resultant.

**Results**

Each of the four parts are separate from each other, but they share the 3 different methods to determine their results. For each of the four parts, make a comparison of the graphical method to the mathematical, and a comparison of the simulation method to the mathematical, using the percent error equation.

**Questions for Discussion**

1. If you had three equal magnitude forces, all three applied to the same point, and one of the forces is directed along the X-axis, what angles would the other two vectors need to be to result in a zero net force?
2. In Parts 1 and 2 you are finding the components of a velocity vector equal in magnitude to 20 m/s. They have the same magnitude, but not the same values for the X- and Y-components. Explain why this is so.
3. This experiment involved adding two and three vectors together. Describe how, graphically, you would represent subtracting a vector from another vector.
4. Is it possible to add a force vector to a velocity vector when representing increasing the velocity of an object by applying a force? If so, show a vector diagram representing this, along with the Resultant vector. If not, explain why not.