STUDENT OUTCOMES

Through this experiment, students will learn:
- Vector analysis
- Resultant vs equilibrant vectors
- Experimental errors
- Statistical Analysis

A scalar is a physical quantity that possesses magnitude only. Examples of scalar quantities are mass, time, density, and temperature. A vector is a quantity that possesses both magnitude and direction; examples of vector quantities are velocity, acceleration, and force. A vector can be represented by an arrow pointing in the direction of the vector, the length of the line should be proportional to the magnitude of the vector.

Vectors can be added either graphically or analytically. The sum or RESULTANT of two or more vectors is a single vector which produces the same effect. For example, if two or more forces act at a certain point, their resultant is that force which, if applied at that point, has the same effect as the two separate forces acting together. The EQUILIBRANT is defined as the force equal and opposite to the resultant.

Those two concepts of resultant and equilibrant vectors are the keys to this experiment. Please spend some time practicing your vector addition using the graphical applet at:

http://www2.hawaii.edu/~pseng/labs/applets/Vectors/index.html

In this applet, the green line has no direction (which is an omission and a bummer). Hence, the direction of this line from the origin to the blue vector is the resultant vector while the equilibrant is the vector
pointing from the blue vector back to the origin. Remember that both resultant and equilibrant vectors have the same magnitude but opposite direction.

The force table is an apparatus that allows the experimental determination of the resultant of force vectors. The rim of the circular table is calibrated in degrees. Forces are applied to a ring around a metal peg at the center of the table by means of strings. The strings extend over pulleys clamped to the table and are attached to hangers. The direction of the forces may be adjusted by moving the position of the pulleys. The magnitude of the forces are adjusted by adding or removing masses to the hangers.

The forces used on the force table are actually weights, or

\[ W = mg \]

In this exercise, we will simply consider the "force" as the mass that is hung on the string, that is, we will not multiply the mass by the acceleration due to gravity.

In this experiment, two methods for vector addition will be used: the graphical method (head to tail method) and the experimental method (using the force table). A third component method will also be used in the result section.

**MATERIALS**

<table>
<thead>
<tr>
<th>Tablet PC Computer Laptop</th>
<th>Force Table, pulleys, hangers, masses</th>
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</thead>
<tbody>
<tr>
<td>Protractor</td>
<td>Word</td>
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<td>Ruler</td>
<td>Quadrille paper</td>
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**PROCEDURE and RESULTS**

1. Vector addition 1: To find the resultant of two forces: a 200 g force at 45 degrees and a 200 g force at 135 degrees.
   a. Place one pulley at 45 degrees and the other at 135 degrees.
   b. On each string that runs over these pulleys, place a mass of 200g (including hanger - each hanger has a mass of 50 g).
   c. With a third pulley and masses, balance the forces exerted by the two 200 g masses. The forces are balanced when the ring is centered around the central metal peg. To balance the forces,
move the third pulley around to find the direction of the balancing force, and then add masses to the third hanger until the ring is centered.

d. The balancing force obtained in (c) is the **equilibrant force**. The resultant has the same magnitude as the equilibrant. To determine the direction of the resultant, subtract 180 degrees from the direction of the equilibrant.

e. Include a graph (leave some space here and paste a piece of quadrille paper whose dimension needs to be at least 6 by 6 inches) where you obtain the equilibrant vector using the graphical method. Make sure to label and include direction/magnitude labels and values of each given vector on your graph. When reading your graphical method, the reader ought to be able to see clearly: the two vectors given with their respective angles, and the equilibrant vector with its angle. Finally, include the scale that you chose.

f. Express each given vector in component notation, add them up and calculate the resultant vector. From your result, express the resultant vector in magnitude and direction. Finally, deduce the equilibrant vector (in magnitude and direction).

**Equilibrant vector summary**

<table>
<thead>
<tr>
<th>Given VECTORS</th>
<th>EXPERIMENTAL</th>
<th>GRAPHICAL</th>
<th>COMPONENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>200 g at 45°</td>
<td></td>
<td></td>
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<tr>
<td>200 g at 135°</td>
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g. Calculate the percent error between the graphical and the component method. Calculate also the percent error between the experimental and the component method. Make sure to do this for both magnitude and direction separately. Based on your PE results, which method is the most accurate?

2. Vector addition 1: To find the resultant of two forces: a 100 g force at 145 degrees and a 150 g force at 250 degrees.

   a. Place one pulley at 145 degrees and the other at 250 degrees.
   b. On each string that runs over these pulleys, place a mass of 100g and 150g respectively (including hanger - each hanger has a mass of 50 g).
   c. With a third pulley and masses, balance the forces exerted by the two other masses. The forces are balanced when the ring is...
centered around the central metal peg. To balance the forces, move the third pulley around to find the direction of the balancing force, and then add masses to the third hanger until the ring is centered.

d. The balancing force obtained in (c) is the **equilibrant force**. The resultant has the same magnitude as the equilibrant. To determine the direction of the resultant, subtract 180 degrees from the direction of the equilibrant.

e. Include a graph *(leave some space here and paste a piece of quadrille paper whose dimension needs to be at least 6 by 6 inches)* where you obtain the equilibrant vector using the graphical method. Make sure to label and include direction/magnitude labels and values of each given vector on your graph. When reading your graphical method, the reader ought to be able to see clearly: the two vectors given with their respective angles, and the equilibrant vector with its angle. Finally, include the scale that you chose.

f. Express each given vector in component notation, add them up and calculate the resultant vector. From your result, express the resultant vector in magnitude and direction. Finally, deduce the equilibrant vector (in magnitude and direction).

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<tr>
<td>100 g at 145°</td>
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<tr>
<td>150 g at 250°</td>
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g. Calculate the percent error between the graphical and the component method. Calculate also the percent error between the experimental and the component method. Make sure to do this for both magnitude and direction separately. Based on your PE results, which method is the most accurate?

3. Vector Addition 3: What is the equilibrant of a force of 200 g directed at 0 degree and another force of 150 g at 250 degrees.
   a. Use the force table to find the equilibrant.
   d. The balancing force obtained in (a) is the **equilibrant force**. The resultant has the same magnitude as the equilibrant. To determine the direction of the resultant, subtract 180 degrees from the direction of the equilibrant.
   e. Include a graph *(leave some space here and paste a piece of quadrille paper whose dimension needs to be at least 6 by*
6 inches) where you obtain the equilibrant vector using the graphical method. Make sure to label and include direction/magnitude labels and values of each given vector on your graph. When reading your graphical method, the reader ought to be able to see clearly: the two vectors given with their respective angles, and the equilibrant vector with its angle. Finally, include the scale that you chose.

f. Calculate analytically (using the components of each given vector) the resultant vector. From your result, express the resultant vector in magnitude and direction, and deduce the equilibrant vector.

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<tr>
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g. Calculate the percent error between the graphical and the component method. Calculate also the percent error between the experimental and the component method. Make sure to do this for both magnitude and direction separately. Based on your PE results, which method is the most accurate?

4. Vector addition 4: To find the resultant of three forces: a 100 g force at 45 degrees, a 150 g force at 135 degrees, and a 80 g force at 270 degrees.

a. Place one pulley at 45 degrees, the other at 135 degrees, and the last one at 270 degrees.

b. On each string that runs over these pulleys, place a mass of 100g, 150g, and 80g respectively (including hanger - each hanger has a mass of 50 g).

c. With a fourth pulley and masses, balance the forces exerted by the three masses. The forces are balanced when the ring is centered around the central metal peg. To balance the forces, move the third pulley around to find the direction of the balancing force, and then add masses to the third hanger until the ring is centered.

d. The balancing force obtained in (c) is the equilibrant force. The resultant has the same magnitude as the equilibrant. To determine the direction of the resultant, subtract 180 degrees from the direction of the equilibrant.
e. Include a graph **(leave some space here and paste a piece of quadrille paper whose dimension needs to be at least 6 by 6 inches)** where you obtain the equilibrant vector using the graphical method. Make sure to label and include direction/magnitude labels and values of each given vector on your graph. When reading your graphical method, the reader ought to be able to see clearly: **the two vectors given with their respective angles, and the equilibrant vector with its angle. Finally, include the scale that you chose.**

f. Express each given vector in component notation, add them up and calculate the resultant vector. From your result, express the resultant vector in magnitude and direction. Finally, deduce the equilibrant vector (in magnitude and direction).

### Equilibrant vector summary

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<tr>
<td>80 g at 270°</td>
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g. Calculate the percent error between the graphical and the component method. Calculate also the percent error between the experimental and the component method. Make sure to do this for both magnitude and direction separately. Based on your PE results, which method is the most accurate?