LAB #2: ADDITION AND COMPONENTS OF VECTORS

OBJECTIVES:

To learn how vectors add by combining them mechanically and graphically.

EQUIPMENT:

<table>
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<tr>
<th>Equipment Needed</th>
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<tbody>
<tr>
<td>Measurement Equipment Tray</td>
<td>1</td>
<td>Vector Lab Container</td>
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<tr>
<td>Force Table</td>
<td>1</td>
<td>Mass Set</td>
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<tr>
<td>Linear Graph Paper on Front Desk</td>
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SAFETY REMINDER

- Follow all safety instructions.
- Keep the area clear where you will be working and walking.

INTRODUCTION:

In this lab you will be using a force table to combine several different force vectors. The table will allow us to vary the directions and magnitudes of up to four different forces so that we can determine what is required for a group of vectors to add to zero.

PROCEDURES:

Answer all of the questions on this handout.

PART 1: Determining a vector from its components

In your Vector Lab Container you will find four pulleys, four 50-gram mass hangers, a metal ring with four strings attached, and a metal pin. Attach a pulley to the force table at the $0.0^\circ$ mark. Attach the other three at $90.0^\circ$, $180.0^\circ$, and $270.0^\circ$. Put the metal pin in the hole in the center of the force table. Put the metal ring over the central pin (or remove the pin and put it through the ring if necessary) and hang the strings over the pulleys. Attach a mass hanger to each string. They should all hang freely with the ring in equilibrium at the center of the table. We will say that the forces are in equilibrium whenever the pin can be easily centered on the pin. Remove the pin and push the ring to one side. You will notice that the ring moves back near the center hole. It may not center itself exactly, but if you can place the ring directly over the hole without it moving off, we will assume that the forces are then in equilibrium.
Put 150g on each pulley at 0.0° and 180.0°, and 200g on each pulley at 90.0° and 270.0°. (Remember to include the 50-gram mass hanger as part of the 150g and 200g masses!) The ring should still be in equilibrium at the center of the table.

You now have four forces all acting in different directions, +x, +y, −x, and −y, and yet they all cancel each other out. It should be fairly obvious why. The forces at 0.0° and 180.0° (\(F_1\) and \(F_3\), respectively) cancel each other because they are equal and pulling in opposite directions, and the forces at 90.0° and 270.0° (\(F_2\) and \(F_4\) respectively) cancel each other for the same reason. To determine the magnitude of the forces, we need to determine the weight of the masses. Using the relationship that

\[
\text{Weight} = \text{W} = \text{Mg} = \text{Mass x (acceleration due to Gravity)}
\]

we have for the 150g = 0.150kg mass that

\[
W = (0.150\text{kg}) (9.80\text{m/s}^2) = 1.47\text{N}.
\]

1. **What is the magnitude of the forces \(F_2\) and \(F_4\)?**

We will now try to replace the two forces \(F_1\) and \(F_2\), with a single equivalent force that is equal to the vector sum of \(F_1\) and \(F_2\), which we will call force \(F_{12}\).

To add vectors graphically, we draw them head to tail, and the vector sum then points from the tail of the first vector to the head of the second vector. Using the Pythagorean Theorem, determine the magnitude of \(F_{12}\).

2. **What is the magnitude of \(F_{12}\)?**

3. **To what mass does this force correspond?**

Using the inverse tangent, determine the angle \(\theta\) to the nearest 0.1°.

4. **What is the angle \(\theta\)?**

Remove the forces \(F_1\) and \(F_2\). Move one of the pulleys to the angle you found in Question 4. Hang the mass you found in Question 3 on this pulley.

5. **Are the three forces in equilibrium? (If not, redo your calculations!)**

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Since the single force $\mathbf{F}_{12}$ balances the two forces $\mathbf{F}_3$ and $\mathbf{F}_4$ just like $\mathbf{F}_1$ and $\mathbf{F}_2$ did, then $\mathbf{F}_{12}$ must be equivalent to the combination of $\mathbf{F}_1$ and $\mathbf{F}_2$. We will now demonstrate this vector addition graphically.

On a piece of graph paper, draw a diagram to scale of the vector sum of $\mathbf{F}_1$ and $\mathbf{F}_2$. Use a scale of $1.0\text{N} = 10.0\text{cm}$. Turn in your drawing with this lab.

6. What is the magnitude of the vector sum in your diagram?

7. What is the value of the angle $\theta$ in your diagram to the nearest $0.1^\circ$?

**PART 2: Determining the resultant of two vectors**

Remove all of the masses from the pulleys. Move two of the pulleys so that one is at an angle of $30.0^\circ$ and one is at an angle of $60.0^\circ$. Place a total of $150\text{g}$ at $30.0^\circ$. This will now be $\mathbf{F}_1$. Place a total of $200\text{g}$ at $60.0^\circ$. This will now be $\mathbf{F}_2$.

8. What is the magnitude of $\mathbf{F}_1$?

9. What is the x-component of $\mathbf{F}_1$?

10. What is the y-component of $\mathbf{F}_1$?

11. What is the magnitude of $\mathbf{F}_2$?

12. What is the x-component of $\mathbf{F}_2$?

13. What is the y-component of $\mathbf{F}_2$?

14. What is the x-component of the sum $\mathbf{F}_1+\mathbf{F}_2$?

15. What is the y-component of the sum $\mathbf{F}_1+\mathbf{F}_2$?

16. What is the magnitude of the sum $\mathbf{F}_1+\mathbf{F}_2$?
17. What is the angle (to the nearest 0.1°) from the x-axis of the sum $F_1 + F_2$?

18. If you were to add a third force vector to $F_1$ and $F_2$ to cancel them out, what would its magnitude and angle be?

19. What mass would you have to put on the pulley to get this force?

20. Put this mass on at the appropriate position. Are the forces in equilibrium? (If not, redo your calculation!)

Draw another scale diagram showing the vector addition of your new $F_1$ and $F_2$. You might need to use a different scale in order to keep it on one sheet of graph paper. Turn in this diagram with your lab.

21. What is the magnitude of the sum $F_1 + F_2$ in your diagram?

22. What is the angle of the sum $F_1 + F_2$ from the x-axis?

PART 3: Determining the resultant of three vectors

Leave $F_1$ and $F_2$ where they are. Add a third pulley at an angle of 135.0° and place 150g on it. We will call this force $F_3$.

23. What is the x-component of $F_3$? (Notice the direction.)

24. What is the y-component of $F_3$?

Use the results from PART 2 to help you answer these questions.

25. What is the x-component of the sum $F_1 + F_2 + F_3$?

26. What is the y-component of the sum $F_1 + F_2 + F_3$?

27. What is the magnitude of the sum $F_1 + F_2 + F_3$?
28. What is the angle (to the nearest 0.1°) from the x-axis of the sum $F_1 + F_2 + F_3$?

29. If you were to add a fourth force vector to $F_1$, $F_2$, and $F_3$ to cancel them out, what would its magnitude and angle be?

30. What mass would you have to put on the pulley to get this force?

31. Put this mass on at the appropriate position. Are the forces in equilibrium? (If not, redo your calculation!)

Draw another scale diagram showing the vector addition of $F_1$, $F_2$, and $F_3$. You might need to use a different scale in order to keep it on one sheet of graph paper. Turn in this diagram with your lab.

Clean-Up

Replace the masses onto the mass holder. Make sure you have all the masses you started the lab with and return any if you had to borrow some. Replace the pulleys, mass hangers, ring with the strings, and the metal pin into the Vector Lab Container. Replace the rulers and protractors into the Measurement Equipment Tray.