**How Much Does the Brick Weigh?**

**Introduction:**

Force is a vector quantity as is displacement, velocity and acceleration. When a body is in static equilibrium (not accelerating), the vector sum of all the forces acting on the body must be zero: F = 0. In this lab, you will analyze several forces that are balanced in equilibrium using the graphical method for adding vectors, which is also known as the parallelogram method.

To graphically find the resultant of two vectors, use the parallelogram method as follows:

1. Draw the two vectors with a magnitude or size scaled to the actual value. For example, if the force of vector **A** is 5N, then 5N may equal 5 cm.
2. Draw the angle between them using a protractor.
3. Redraw vectors **A** and **B** as in the diagram below such that they are parallel to each other. Use a protractor and a ruler. Use the supplementary angle to obtain the proper directions for the vectors.
4. Draw the resultant between where the tails of the two vectors meet to where they meet again at the tips. The length and angle of this vector is the sum of vectors **A** and **B**.

# R = 7.8N

 = 30

**B = 3.0N**

A = 5.0N

 = 150

**B = 3.0N**

A = 5.0N

A = 5.0N

**B = 3.0N**

# R

To analytically (Component Vector Analysis) find the resultant of two vectors, use the coordinate system and trigonometry as follows:

1. Depending on the nature of the problem, you may place one of the vectors on the x-axis to make it simpler.
2. Using the given angle and trigonometry for right angles, calculate the x and y components of the other vector.
3. Note that since one vector lies on the x-axis, it will have not y component vector.
4. After computing the x and y component vectors, add them together.
5. Use the Pythagorean Theorem to determine the value of the resultant vector **R**.

|  |  |
| --- | --- |
| Ax = A cos | Ay = A sin |
| Ax = (3.0N)(cos 30) | Ay = (3.0N)(sin 30) |
| Ax = 2.6 N | Ay = 1.5N |
| Bx = 5.0N | By = 0.0N |
| Rx = Ax + Bx = 7.6N | Ry = Ay + By = 1.5N |
| $R= \sqrt{R\_{x}^{2}+R\_{y}^{2}}$ $R= \sqrt{(7.6N)^{2}+ (1.5N)^{2}}$ *R =* 7.8N |

y

x

**A = 3.0N**

 = 30

B = 5.0N

**Pre-Lab:**

Given two forces of 20N and 30N acting at a point and separated by an angle of 30, what is the net force required to produce equilibrium? Solve both graphically and analytically (using coordinates) on a separate piece of paper using a protractor, ruler and scientific calculator. Note: the force required for equilibrium will need to oppose the resultant of these two forces.

For this lab, you will have to determine the weight of a brick. A brick will be suspended from a ring attached to two force sensors through two strings attached to a lab stand as seen below. The weight of the brick will create tensional forces in the strings attached between the ring and the force sensors. When the vector sum of these tensions is zero, the ring will be in equilibrium such that it will be in a rest position.

**B**

**A**

**C**

**Purpose:**

To develop the graphical method used in the resolution and composition of forces.

**Materials:**

|  |  |
| --- | --- |
| * 2 Lab Stands
 | * Ruler
 |
| * 2 Vernier Force Sensors
 | * Protractor
 |
| * 1 Vernier Lab Pro
 | * Paper
 |
| * 1 Brick
 | * Key ring
 |
| * String
 | * Masking Tape
 |

**Procedure:**

1. Attach two force sensors and a ring to the lab stand. Note that they do not have to be exactly as shown in the diagram above. You may need to use masking tape to keep the string from moving.
2. Attach a brick to the ring as shown in the diagram.
3. Place the setup against the whiteboard or SmartBoard.
4. Connect the force sensors to a Vernier Logger Pro.
5. Open the program Logger Pro 3.5.0 or greater. You should notice that the two force sensors (Force 1 and Force 2) will be shown on the lower left hand corner of the screen.
6. Set up a slide projector, overhead projector, SmartBoard projector, or some other suitable light source to shine on the brick setup such that a well-defined shadow can be projected onto the whiteboard.
7. Place a piece of paper against the Whiteboard and make two marks for each string where the shadow is projected. Use a straight edge to connect these points such they all converge to a common point where the ring was located. **Your ring should ideally be centered on your sheet.**
8. Label the two lines with the force gauge measurement values in newtons. The third line is the unknown weight of the brick that you will have to determine through graphical and component vector analysis.
9. Adjust the angles of the strings and repeat the process for another group.

**Data Summarization (Graphical):**

1. Let's begin by connecting your three sets of points to form three lines that will hopefully converge to a point. Don't worry if they do not perfectly converge to a point.
2. Label the line attached to the force sensor on the right with an **A**, then continue in the counterclockwise direction and label the next line with the other force sensor with a **B,** and finally label the third line with the brick with a **C**. *See the diagram on the previous page if you are confused.*
3. Enter the corresponding values for the forces A and B in your data table below.
4. Summarize the data graphically:
* Determine a scale for your drawings. *Warning, do* ***NOT*** *use 1cm = 1N.*
* Place an arrowhead at the length determined based upon your scaling.
* Graphically add Forces A and B using the tip-to-tail method (as done in the pre-lab) to find the resultant, R. **Make sure all vectors have arrowheads.**
* Measure the resultant’s length in cm and convert back to a force in newtons using your scale. **Record both these values on your vector diagram, and put the value in newtons in your data table.** ***Make sure you show your work for this calculation.***
* **Draw the equilibrant to R and label it with its magnitude**.
* **It is at this point that you want to ask your teacher for the information necessary to determine the weight of the brick.**
* **Brick**
	+ **Mass =**

**Graphical Summary:**

|  |  |  |
| --- | --- | --- |
| **Force A** | **Force B** | **Resultant (A + B)***(Careful, in vector addition, you cannot simple add Force A to Force B like adding two numbers together. It does not work that way with vectors unless they are pointing in the same direction. Use the value from your drawing.)* |
|  |  |  |
| Use this space to determine the weight of your brick from the information above. ***You must show all work, including the equation and the substitution with units.*** |  |
| **Weight of Brick** |  |
| **% Difference** |  |

* **Now that you have determined the weight of the brick use your scale to convert the weight into a vector and place an arrowhead at that distance from the center point on line C.** *Do not be surprised if Vector C is aligned with the equilibrant you just drew.*

**Data Summarization (Analytical/Component Vector Analysis):**

1. Use the same drawing used for the graphical analysis.
2. Draw an x and y-axis such that the y-axis is aligned with your third line (**C**), and the x-axis cuts across where the three lines meet in the middle.
3. Summarize the data analytically:
* Measure the angle between your resultant and the x-axis, and record this value on your drawing.
* **Calculate the x and y components for each vector, and then draw them on your diagram, and record the values in your data table**. ***Make sure you show your work for these calculations on your drawing.***
* Using your component vectors, determine the resultant vector. Again, make sure you show this calculation on your drawing.

**Component Vector Summary**

|  |  |
| --- | --- |
| **Force A** | **Force B** |
|  |  |
| **Angle relative to x-axis** | **Angle relative to x-axis** |
|  |  |
| **X-Component** | **Y-Component** | **X-Component** | **Y-Component** |
|  |  |  |  |
| **Sum of X-Components (Rx)**  |  |
| **Sum of Y-Components (Ry)** |  |
| **Resultant**  |  |
| **Weight of Brick** *(from 1st table)* |  |
| **% Difference** |  |

**Analysis:**

1. What is the significance of the equilibrant? How does it relate to your graphical drawings?

**Graphical Comparison:**

1. Compare the values for the resultant vector determined graphically to the actual weight of your block.
* Are they similar or different? *i.e. Does the resultant of A and B equal C? See your percent error.*

**Analytical Comparison:**

1. Compare the values for the resultant vector determined analytically to the actual weight of your block.
* Are they similar or different? *i.e. Does the resultant of A and B using component vectors equal C? See your percent error.*

* What is the relationship between the horizontal components of forces A and B? How does it relate to your drawing?

**Error Analysis:**

* **What are some sources of error involved with this lab exercise?**

**Conclusion:**

* **What can you conclude about the two methods used to determine the weight of the brick?**

**Scale: =**