2 Vectors

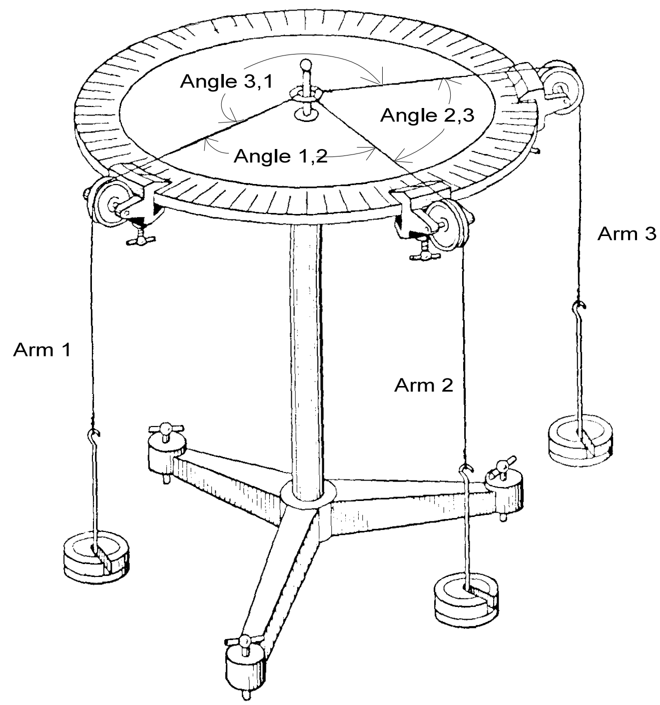
Name______________________

Lab: The Force Table

AP/Inquiry Physics

In this laboratory, you will explore the properties and relationships of ***vector*** quantities. Such quantities have both magnitude and direction. These quantities can be manipulated mathematically using special rules of **vector math**. We will be studying force relationships because forces are vector quantities; they have both magnitude and direction.

Your group will be using a **force table**. It is a circular platform with four rotating arms attached at a central point. You will be using three of the four arms in this lab. On the three arms you will place strings attached to a central ring. Weights will be hung from weight holders on the ends of the strings. The arms (and strings and weights) will then be moved until the central ring is centered.



A. To begin, check that three of the four arms on your table have strings threaded over the pulleys. Check that each string has a weight holder attached to it.

B. Place weights on each weight holder so that the total weight on each arm is different from the others. (The fourth arm will remain unused throughout the lab.)

C. Once you have placed the weights, rotate the three arms until you can center the ring that the strings are attached to. **Make certain that the ring is perfectly centered before proceeding.**

D. Decide which arm is arm 1, which is arm 2, and which is arm 3.

E. Record in the table under "Trial 1" the **total** force on each arm. ***Add 14 grams to each reading to account for the weight of the weight holders themselves.***

F. Use the markings on the force table to measure the angle between each pair of arms. Record the angles in the table. See the diagram for help in deciding how the angles are labeled.

G. Finally, **repeat the entire procedure** using **different angles and weights**. Record the new data under "Trial 2" in the table.

Trial	Force	Angles between arms
1	arm 1	1,2
	arm 2	2,3
	arm 3	3,1
2	arm 1	1,2
	arm 2	2,3
	arm 3	3,1

The Idea

1. Consider arm 2. The force on arm 2 is pulling in a different direction than the forces on arms 1 and 3. The ring remains centered, however. Explain how the ***size and direction*** of the force on arm 2 compares to the size and direction of the ***combination*** of forces 1 and 3.

The class will need to discuss the above question before we continue.

The class will work together to form a class hypothesis regarding the lab. Write it in the space below.

Class Hypothesis (expressed as a written statement)

The relationships between force vectors can be written as vector equations. For example, if we wanted to say that force Q is equal to half of the sum of forces D and Z, we would write:

$$\vec{Q} = \frac{\vec{D} + \vec{Z}}{2}$$

The class hypothesis expresses in words a relationship between $\vec{F}_1$ $\vec{F}_2$ $\vec{F}_3$ and .

2. In the space below, show that relationship as a vector equation:

Testing the Hypothesis

We can easily test our class hypothesis by graphically adding two of the vectors and finding their resultant. You are going to draw a scale drawing of the Trial 1 data on a sheet of graph paper. The scale drawing will be a picture of the three force vectors you experimented with. In that picture, the length of an arrow represents a specific amount of force. **Pick either a scale of 1 cm = 20 g OR a scale of 1 cm = 10 g; use whichever makes the diagram large without going off the edge of the paper.** For example, a scale of 1 cm = 20 g means that if a force is 114 grams, an arrow 114 / 20 or 5.7 centimeters long will represent that force.

Your scale diagram will have three arrows coming from a central point. Each arrow represents one of the three force vectors. The direction of each arrow is determined using the angle data from the table. (See Figure 1.)

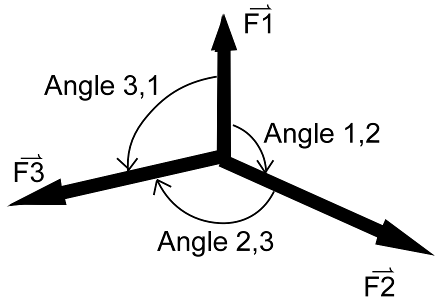


Figure 1

A. Draw the vector for force 1 first. It will be an arrow pointing straight upward (north) from the center of the graph paper. Make the arrow the appropriate length to match the size of force 1. Label your arrow.

B. Now draw the vector for force 2. It will also be an arrow pointing outward from the center of the graph paper. You must use the data you recorded in the table to determine how many degrees away from the force 1 vector (from north) you should draw the force 2 vector. Make the force 2 vector the appropriate length to match the size of force 2. Label your arrow.

C. Finally draw the vector for force 3. Check that the angles between it and vectors 1 and 2 match your data. Make the force 3 vector the appropriate length to match the size of force 3. Label your arrow.

D. **CAREFULLY** check that each vector is the proper length and that you have properly measured the angles between the various vectors.

E. Add vector **F1** to **F3** by drawing a copy of **F1** at the head of **F3** as shown in Figure 2.

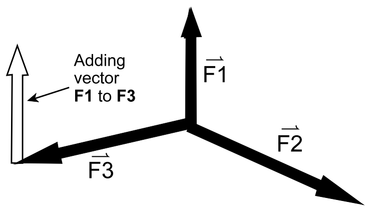


Figure 2

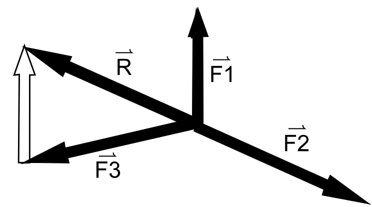


Figure 3

F. Since the two vectors we are adding are now drawn head to tail, we can find their resultant. Draw an arrow from the center of the paper (where **F1**, **F2**, and **F3** originate) to the head of the last added vector. Label that new arrow vector **R**. Your drawing should now look something like Figure 3.

TRIAL 1 DIAGRAM

3. Vector **R** is the ***resultant*** of the two vectors **F1** and **F3**. Measure the length of your resultant **R**. What is its corresponding force value in **grams**? __________

4. What theoretical value (in grams) does the class hypothesis predict for **R**? __________

5. We will determine how well your data fits your prediction by comparing your measured value from question 2 to the theoretical value from question 3. We will compute the ***percent error*** between those two values with the formula at right. Note that the absolute value is taken of the numerator, so percent error is always positive.

$$\%\ error = \frac{|measured - theoretical|}{theoretical} \times 100$$

What was the percent error between your actual and predicted values for R?
SHOW YOUR WORK

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Vectors have direction as well as magnitude. You have measured the magnitude or size of **R** and compared it to its hypothetical or theoretical value. Now you will examine how well your data supports the portion of your hypothesis regarding direction.

6. Look at the class hypothesis. It can be interpreted so that it predicts the theoretical angle between **F2** and **R**. Give that theoretical value (in degrees): __________

7. Now use your protractor to measure the actual angle between vectors **R** and **F2**. Give that measured value (in degrees): __________

8. Use answers 6 and 7 to compute the percent error for the direction of the resultant. SHOW YOUR WORK

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TRIAL 2 DIAGRAM

Draw another scale diagram using the Trial 2 data from the table. Add **F1** and **F3** and measure the magnitude of the new resultant **R**, and answer the questions below.

9. **New R** for Trial 2 = ______________ grams; *Theoretical* R for Trial 2 = __________ grams

10. Calculate the percent error for the Trial 2 resultant's length. SHOW YOUR WORK

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Now show the measured and theoretical angles between **R** and **F2** for the second trial.

11. New Angle Between **R** and **F2** for Trial 2 = _________ ; *Theoretical* Angle = _________

12. Calculate the percent error for direction of the new resultant. SHOW YOUR WORK

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Conclusions

13. What do the results tell you about force vectors?

Conclusion Guidelines:
Write in complete sentences and do not use the first person (I, we, our, etc.).
Include the following:
A. Restate the hypothesis.
B. State the range (lowest and highest values) of percentage error.
C. Discuss whether that range of error is explainable by *systematic* errors, and discuss the likely sources of such errors (equipment problems/limitations and other significant issues that could not be corrected). Be specific and reasonable, avoiding vague terms like "human error" and ignoring trifles like the difficulty of using a pencil or protractor.
D. Given above discussion, indicate if the experiment supported or refuted the hypothesis.

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