

PHYS XXXX-L

Title (of Lab)

Name (your name)

Date of the lab (date performed)

Dr. Thomas Eaves

The laboratory report is designed to answer the following questions:

- a. What did you try to find out?
- b. How did you do it?
- c. What results did you obtain?
- d. What do the results mean?

To answer these questions, a five section (typically 5 paragraphs) format will be used. These sections are described below:

1. Abstract:

A **brief** (one paragraph) summary of the purpose, method, and significant results of the experiment.

2. Objective(s):

Provide a short statement of the objective(s) of the experiment.

3. Theory:

Describe the fundamental physics required to address your objective. If you are attempting to determine the value of some specific quantity, provide the mathematical relationship for that quantity in terms of the variables you will measure in the laboratory. Briefly address what data are to be taken and how they will be manipulated to yield a result. Any assumptions or simplifications should be stated.

4. Apparatus and experimental procedures:

Describe the equipment you use in the experiment. Provide a sketch of the experimental apparatus with parts labeled. Describe how the apparatus is used to measure the quantities described in the theory paragraph.

5. Data:

Present data and the resulting calculations made upon these data in tabular form. In this section you will place graphs of data relationships. You will use an electronic spreadsheet to present all data and supporting calculations. Include units for measured quantities in the data table(s). Clearly label all rows and columns in your tables and include units.

Graphing. Data should be displayed graphically.

- a. Use a spreadsheet program or computer graphing program to produce your graphs. Data will be represented as points.
- b. Do not connect data points with line segments. Use best fit curves to show the relationship between the quantities being graphed. If your graphing software does not have curve fitting capabilities, use a French curve to draw smooth curves by hand on your graphs.
- c. Be sure to title your graphs and label their axes. Include units in your axes labels.
- d. If you plot more than one dependent variable curve on the same graph, be sure you indicate which curve is which.
- e. Indicate any key features on the graph itself.

5. Results and Conclusions:

a. Results: State the result(s) of your experiment. If the result is numerical, insure that you include units.

b. Conclusions: Discuss the meaning of the results presented in paragraph 5a. Discuss sources of error in the experiment.

Word processing.

- a. With the exception of graphs of data, all laboratory report parts will be typed (a spreadsheet is encouraged for paragraph 4). Use of a word processor is highly recommended. Graphs do not have to be integrated into text, but should be placed in the order they are introduced in the text.
- b. Double space all material except that contained in spreadsheets.
- c. Spelling, punctuation and grammar. Papers with many or serious errors in spelling, punctuation or grammar will lower your grade.

SAMPLE REPORT

PHYS XXXX-L

Vectors

Sam Smith

February 7, 2011

Dr. Thomas Eaves

Abstract:

Vectors are mathematical entities that represent physical variables that can only be accurately defined in terms of both magnitude and associated direction. Force is a physical entity that requires knowledge of both the *amount* as well as the *direction* the force is acting before we can fully understand it. Since we live in a three dimensional world, and forces can act in more than one direction, we use vectors to determine the force components. We can do this by converting the polar coordinates of the force to Cartesian components.

Objective(s):

To see if the result of applying three forces on an object can be determined by ADDING the three forces as VECTORS.

Analytical Method

Theory:

To add two or more vectors together, it is first necessary to express each of the vectors in rectangular components, (A_x, A_y) . If a vector is expressed in polar form (A, θ) , where A is the magnitude and θ is the angle indicating direction, then the rectangular components can be found using the basic trigonometry of a right triangle:

$$(1) \quad A_x = A \cos \theta \quad A_y = A \sin \theta$$

Then all the x-components of the vectors are added together to obtain the resultant x-component, R_x , all the y-components are added to obtain the resultant y-component, R_y , and if in 3-D, the same goes for the z-components:

$$(2) \quad R_x = \sum A_x \quad R_y = \sum A_y$$

Once the rectangular components of the resultant vector have been obtained, the magnitude R of the resultant vector can be obtained using the Pythagorean Theorem:

$$(3) \quad R = \sqrt{R_x^2 + R_y^2}$$

The angle that the resultant vector makes with the x-axis, θ_R , can be determined using the basic trigonometry of a right triangle:

$$(4) \quad \theta = \tan^{-1}(R_y/R_x)$$

Graphical Method

Theory

(How you do it)

To add two or more vectors together graphically, it is first necessary to set up a coordinate system. For vectors expressed in polar coordinates, an origin and a horizontal line are needed. Then each vector can be expressed as a directed line segment on this graph. The length of the line is determined by the magnitude of the vector according to some scale. The direction of the line is determined by having the line segment directed at an angle θ measured counterclockwise from the horizontal coordinate line (or from some line parallel to the horizontal coordinate line) where θ is equal to the angle of the vector. The first vector starts at the origin. The next vector starts at the tip of the first vector. And each additional vector to be added starts at the tip of the preceding vector. The resultant is then obtained by drawing in a line segment from the origin (tail of the first vector) to the tip of the last vector. The length of this segment then gives the magnitude of the resultant vector, and the angle measured from the horizontal axis gives the angle of the resultant vector.

Experimental Method (Using the Force Table)

Theory

The three forces representing the three vectors to be added are applied to the ring on the force table by setting a pulley on the force table at the angle corresponding to each of the three vectors and then attaching weights corresponding to the magnitude of each vector to strings hung over the pulleys. The angle and weight needed to balance the system and keep the ring centered on the post determine a fourth vector, \vec{E} , such that all four vectors add to the zero vector:

$$(5) \quad \vec{A} + \vec{B} + \vec{C} + \vec{E} = 0$$

or,

$$(6) \quad \vec{A} + \vec{B} + \vec{C} = -\vec{E} = \vec{R}$$

Therefore the resultant vector, \vec{R} , is equal in magnitude to \vec{E} but oppositely directed. Thus the angle determined on the force table is 180° different from the angle of the resultant vector.

Apparatus and experimental procedures:

Procedure: Analytic

Add each of the three sets of vectors analytically. Express the resultant vectors in polar form, i.e. find the magnitude and angle of each of the resultant vectors.

Procedure: Graphical

Add each of the three sets of vectors graphically. Warning: placing the origin in the middle of the paper is not always the best - you may run out of room on the paper! Use a scale of such as 1 cm for 20 grams. Estimate how accurately you can draw and measure each length and angle.

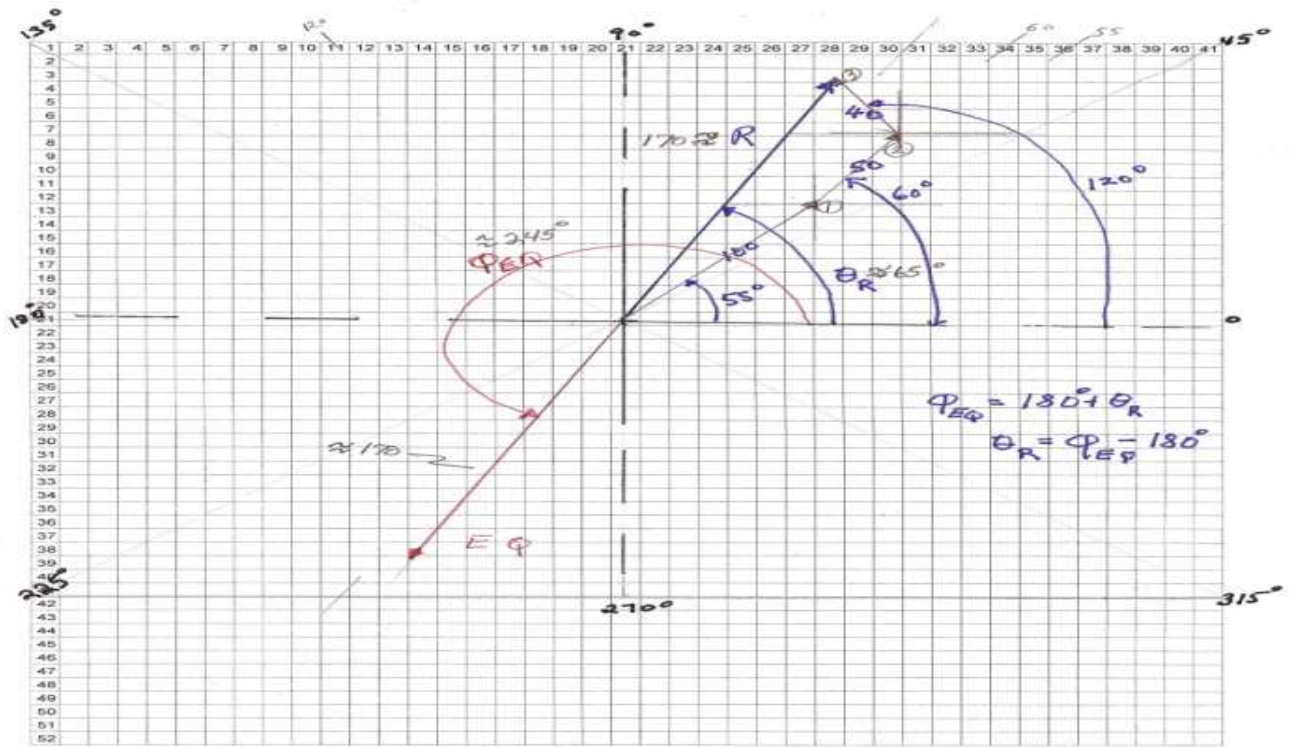
Procedure: Experimental

Add each of the three sets of vectors using the force table. (NOTE: The weight holder has a weight of 50 grams. Should this be included in your weight determination?) Estimate how well you can set and measure the angles, and estimate how well you can determine the mass of the fourth vector \vec{E} .



Fig. 5: Force table and masses

DATA: Graphical



Force Table:

	m_1 (g)	θ_1 ($^\circ$)	m_2 (g)	θ_2 ($^\circ$)	m_3 (g)	θ_3 ($^\circ$)
1	50	90	100	180	100	270
2	100	55	50	60	40	120
3	150	30	150	60	60	270

Analytical:

The second method, the analytical method, employed only calculations. No data were taken.

Calculations:

PART 1

For the first, graphical, part, we have to first convert the magnitude from grams to centimeters. To do this, we will use the scale factor of 20 grams = .5 cm.

$$R_A = 150 \text{ grams} * (.5 \text{ cm} / 20 \text{ grams}) = 3.75 \text{ cm};$$

$$R_B = \text{_____ cm};$$

$$R_C = \text{_____ cm}.$$

PART 2

For the second part, we have to determine the resultant vector, R, from the equilibrant vector, E:

$$\Theta_R = \Theta_E \pm 180^\circ.$$

$$\Theta_R = \Theta_E \pm 180^\circ = 245^\circ \pm 180^\circ = 65^\circ$$

PART 3

For the third, analytical, part, we have to first convert all the vectors from the given polar form into rectangular form:

$$\text{Vector A: } 150 \text{ gm at } 0^\circ : R_A = 150 \text{ gms}; \theta_A = 0^\circ$$

$$A_x = R_A * \cos(\theta_A) = 150 \text{ gm} * \cos(0^\circ) = 150 \text{ gm}; \quad B_x = 100.0 \text{ gm}; \quad C_x = -129.9 \text{ gm}$$

$$A_y = R_A * \sin(\theta_A) = 150 \text{ gm} * \sin(0^\circ) = 0 \text{ gm}. \quad B_y = 173.2 \text{ gm}; \quad C_y = 75.0 \text{ gm}$$

Next we have to add all of the x components to get the total x component:

$$X_R = A_x + B_x + C_x = 150.0 \text{ gms} + 100.0 \text{ gms} - 129.9 \text{ gms} = 120.1 \text{ gms}$$

$$Y_R = A_y + B_y + C_y = 0.0 \text{ gms} + 173.2 \text{ gms} + 75.0 \text{ gms} = 248.2 \text{ gms}$$

Finally, we convert from the rectangular form back to the polar form:

$$R = [X_R + Y_R]^{1/2} = [(120.1 \text{ gms})^2 + (248.2 \text{ gms})^2]^{1/2} = 275.73 \text{ gms}$$

$$\Theta = \tan^{-1} [Y_R/X_R] = \tan^{-1} [248.2 \text{ gm} / 120.1 \text{ gm}] = 64.18^\circ.$$

(Since both the x components and the y components are positive, the angle should be in the first quadrant, and it is.)

Results: (Often a table is the best way to show results.)

Set	Analytical	Graphical	Force table (Measured)
5	275.73 gm @ 64.18°	<i>Type in results</i> <i>From graph here</i>	280g ± 10g at 65° ± 1°
6	229.88 gm @ -39.84°	<i>Type in results</i> <i>From graph here</i>	230g ± 10g at -39° ± 2°

Answers to Questions:

1. How close is your calculated mass and angle to the measured mass and angle? How close is your calculated mass and angle to the graphical mass and angle? Was it easy finding exactly one mass and angle that offset the forces?
2. What are some of the random errors that occurred in your measurements?
3. What are some of the systematic errors that occurred in your measurements?

4. How large do you believe is the amount of discrepancy caused by each systematic error?

Conclusion and Discussion:

As you can see from the table of results, our Force Table results were within about 5 grams and within 1 degree of matching the analytical results. Both the magnitude and the angle match up within the range of uncertainty. (You should say a similar thing about how well the graphical matches the analytical and the Force Table results.)

This indicates that we can add force vectors just like we can add position vectors: by breaking the force vectors into components and adding the x components together and adding the y components together to get the result in rectangular components. We can then convert back to polar form since that is usually the nicest way to express our result.