

Lab #1 Addition of Force Vectors

The resultant of two forces acting at the same point on a body is that single force whose effect on the body is the same as the combined effect of the two forces. When two or more forces act at the same time on a body and the vector sum is zero, the object is said to be in "equilibrium". To find the resultant of two forces acting at the same point, a third force can be applied at that same point in such a direction and of such magnitude as to counter-balance the effect of the two forces. Since this third force produces equilibrium, it is called the equilibrant. The resultant of two forces is equal in magnitude to their equilibrant but acts in the opposite direction.

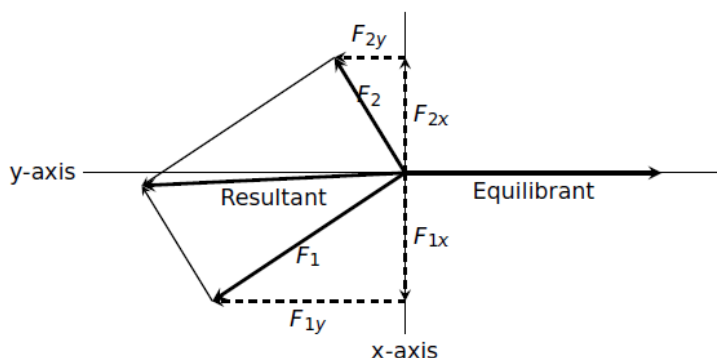
In this lab you will apply the methods of vector addition to experimentally investigate forces in equilibrium.

Procedure:

1. Set up "y" shaped metal frame, ring, strings, & spring scales as shown in demo.
2. Adjust apparatus until equilibrium is achieved (ring is not touching center pin) - tighten the knob to lock it.
3. Make sure that no meter is reading off scale.
4. Place a large sheet of paper under the apparatus.
5. Mark lines of force with a sharp pencil on tiny slits.
6. Extend three force lines to meet at center point.
7. Record the force readings of each meter next to the corresponding lines.
8. Select a scale to convert Newtons to cm (e.g. 1 N = 1 cm)
9. Mark off each force vector at its appropriate length (the length represents the magnitude).
10. Label the two shorter vectors F_1 & F_2 .
11. Label the longer line "equilibrant".
12. Using the parallelogram method for tail to tail vectors, create the resultant of F_1 & F_2 . (See diagram.)
13. Label the resultant.
14. Draw a line through the center point running perpendicular to the equilibrant.
15. Label this new line "x axis" and label the equilibrant "y axis" (if it does not line up perfectly with the resultant, extend the y-axis up along side the resultant.)
16. Using triangulation methods on the diagram itself, draw the x & y components of both F_1 & F_2 .
17. Use the ruler to measure these x & y components in order to determine their magnitudes (in Newtons). Do this for both the F_1 & F_2 vectors.

Questions:

1. What is the vector sum of F_{1x} & F_{2x} ?
2. What is the vector sum of F_{1y} & F_{2y} ?
3. How does the sum of F_{1y} & F_{2y} compare to the resultant you drew on your diagram?
4. How does the resultant compare to the equilibrant?
5. Under what conditions would the readings on all three meters be identical?
6. On an empty corner of your diagram sheet, draw (to scale and with careful attention to the angles) a tip to tail vector diagram of F_1 , F_2 & the equilibrant. What does this mean?



Lab Write-ups

When writing a lab, **do not use a title page**. At the top of the page in the left corner, place your name, with your lab partner(s)'s name(s) underneath. In the center, write the title of the lab and in the right corner, write **the date(s) on which the experiment was conducted**.

Each lab should contain the following sections in the write-up (in this order):

Introduction: This section indicates the purpose for doing the lab and outlines any theory or explanation required for the lab (including equations). It is written in paragraph form.

Equipment: This is just a list of equipment used for the lab. Do not include pencil and paper unless they were actually used to *conduct* the lab.
↳ including what variables represent.

Procedure: *→ See lab sheet.* This explains what was done during the lab. If the procedure is given to you, you do not need to repeat it. Reference it (e.g. See attached handout for procedure). You may also include diagrams of the equipment set up if necessary or convenient.

Data and Calculations: Data is any measurement or observation used in the experiment. If, for example, you start measuring one end of an object at the 10.00 cm mark on the ruler and find the other end at 16.35 cm, you must record **both** of these values. Often your data will be organized in tables.

Calculations include any graphs you produce. If a calculation is repeated several times, just show one example. However, all slope and percent difference calculations must be shown, or ~~calculations involving error analysis.~~

Sources of Error: Lists sources of random and systematic errors. List all precision measures of all devices used. Be quantitative with sources of errors wherever possible (how big is the error likely to be?) Try to pick out the most important source of error. Discuss whether or not the results are expected or not. Try to explain any anomalies.

Conclusion: The conclusion is concise, specific and quantitative if possible. The conclusion refers back to the purpose of the lab and answers it by giving the specific results supporting your conclusions.
with numbers

Discussion: Answers to questions answered in the lab are placed here. If you have written the procedure, you would also suggest how you may change the procedure were you to do it again or if you had more time.

Discussions and conclusions are SEPARATE sections! The discussion will typically take half a page (or more) but the conclusion will usually be 1/3 of a page or less.

N.B. Labs are due one week after they have been conducted in class. If you require time outside of class to complete the lab, or if you miss the lab day, you must complete the lab within 1 week. Labs not handed in by the due date will receive a zero. You will hand in one lab per lab group for all formal labs.

Sources of Error

Limitation of Equipment

- Analog devices

- accuracy is typically smallest division of measure

- precision measure $\pm \frac{1}{2}$ accuracy

e.g. meterstick - accuracy 1mm
- p.m. ± 0.5 mm

- Digital device - accuracy is typically smallest division
- p.m. \pm accuracy

e.g. stopwatch - p.m. ± 0.01 s

Limitation of Method.

- friction, parallax, reaction time, etc.
estimate the uncertainty these cause in the measurements and use them in error propagation.

Error Analysis

a, b, c - measured values

$$a \pm \delta a$$

$\delta a, \delta b, \delta c$ - uncertainty in values

↑
lower delta
case

Q = calculated value, δQ - uncertainty in calculated value as a result of uncertainties in measured values.

$$d = 3.54 \pm 0.05 \text{ cm}$$

← 1 digit in uncertainty

$$3.5 \pm 0.2 \text{ cm}$$

↑ ↑
precision of measurement
and uncertainty match

~~$$3.54 \pm 0.2 \text{ cm}$$~~
NWB

Addition and Subtraction

$$2.0 \pm 0.2 \text{ cm} = a$$

$$b = 4.0 \pm 0.3 \text{ cm}$$

$$Q = a + b \quad \delta Q = ?$$

$$= 2.0 + 4.0 \text{ cm}$$

$$= 6.0 \text{ cm}$$

$$(\delta Q)^2 = (\delta a)^2 + (\delta b)^2$$

$$\delta Q = \sqrt{(0.2 \text{ cm})^2 + (0.3 \text{ cm})^2}$$

$$= \sqrt{0.13 \text{ cm}^2}$$

$$= 0.36 \text{ cm}$$

$$= 0.4 \text{ cm}$$

$$Q = \underline{\underline{6.0 \pm 0.4 \text{ cm}}}$$

$$Q = b - a$$

$$= (4.0 \pm 0.3 \text{ cm}) - (2.0 \pm 0.2 \text{ cm})$$

$$= 2.0 \pm 0.4 \text{ cm} \leftarrow \text{same } \delta Q \text{ as addition,}$$

Equality

$$2.4 \pm 0.3 \text{ cm}$$

$$- 2.0 \pm 0.2 \text{ cm}$$

$$\hline 0.4 \pm 0.4 \text{ cm}$$

→
This could be zero
They could be equal
so we say they are
experimentally equal

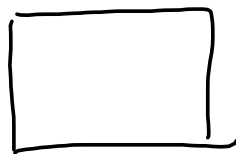
$$2.5 \pm 0.3 \text{ cm}$$

$$\underline{2.0 \pm 0.2 \text{ cm}}$$

$$0.5 \pm 0.4 \text{ cm}$$

↑
This CAN'T be
zero.
These are
experimentally
different.

Multiplication and division



$$a = 2.0 \pm 0.2 \text{ cm}$$

$$b = 4.0 \pm 0.2 \text{ cm}$$

$$Q = ab \quad \delta Q = ?$$

$$= (2.0 \text{ cm})(4.0 \text{ cm})$$

$$= 8.0 \text{ cm}^2$$

$$\frac{\delta Q}{|Q|} = \sqrt{\left(\frac{\delta a}{a}\right)^2 + \left(\frac{\delta b}{b}\right)^2}$$

$$\frac{\delta Q}{8.0 \text{ cm}^2} = \sqrt{\left(\frac{0.2 \text{ cm}}{2.0 \text{ cm}}\right)^2 + \left(\frac{0.2 \text{ cm}}{4.0 \text{ cm}}\right)^2}$$

$$= 0.11$$

$$\delta Q = 0.88 \text{ cm}^2$$

$$= 0.9 \text{ cm}^2$$

$\frac{\delta a}{a}$ = fractional or % uncertainty in a .

$$Q = \underline{\underline{8.0 \pm 0.9 \text{ cm}^2}}$$

Naster functions

$$\sin(30.0 \pm 0.1^\circ) = ?$$

$$\begin{array}{l} \sin 30.1^\circ = 0.502 \\ \sin 30.0^\circ = 0.500 \\ \sin 29.9^\circ = 0.498 \end{array} \left. \vphantom{\begin{array}{l} \sin 30.1^\circ \\ \sin 30.0^\circ \\ \sin 29.9^\circ \end{array}} \right\} 0.002$$

$$\sin(30.0 \pm 0.1^\circ) = 0.500 \pm 0.002$$

To do this properly
we need calculus
(derivatives)

We won't do this...
we'll use WCS
(worst case scenario)