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.

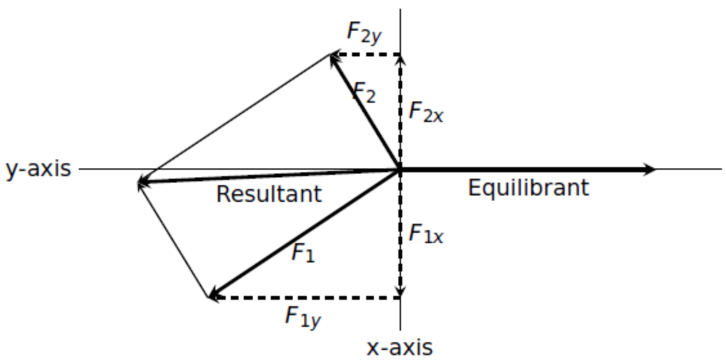
In this lab you will apply the methods of vector addition to experimentally investigate forces in equilibrium.

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):

background info.

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.
and what the variables represent.

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.

→ see lab sheet.

Procedure: 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.

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

Error / Uncertainty of measurement (equipment)

- Limitation of equipment
  - for most analog devices it's ± ½ smallest division (accuracy)

  e.g. meterstick - accuracy 1mm
  - precision measure ± 0.5 mm.

  - for most digital devices it's ± accuracy

  e.g. stopwatch - accuracy 0.01s
  - p.m. ± 0.01s

Error / Uncertainty of Method.

- The way we choose to measure something effects the accuracy of the measurement.

  e.g. parallax, friction, reaction time, etc.
  - you need to estimate the uncertainty in these measurements and use these values in error propagation

Error Analysis

a, b, c ⇒ measured values

δa ← Greek delta Δ, δ

$a \pm \delta a$ ← any measured value

3.24 ± 0.05 cm

3.2 ± 0.2 ← 1 digit in uncertainty

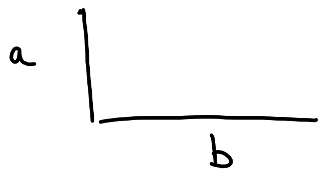
precisions match

Q = calculated value, calculated from measured values.

$\delta Q = ?$

$Q = a + b$

Addition and Subtraction



$Q = a + b$

$= 3.5 + 4.0\,m$

$= 7.5\,m$

$\delta Q = ?$

$(\delta Q)^2 \neq \delta Q^2$

$\delta(Q^2)$

$a = 3.5 \pm 0.2\,m$

$b = 4.0 \pm 0.3\,m$

$(\delta Q)^2 = (\delta a)^2 + (\delta b)^2 \left[+ (\delta c)^2 + (\delta d)^2 + \ldots \right]$

$\delta Q = \sqrt{(0.2\,m)^2 + (0.3\,m)^2}$

$= 0.36\,m$

$= 0.4\,m$

$Q = a + b = 7.5 \pm 0.4\,m$

same

$Q = b - a$

$= 0.5 \pm 0.4\,m$

$3.0 \pm 0.2\,cm$
$3.1 \pm 0.3\,cm$] experimentally equal

Equality

When we subtract 2 things and get zero, we say they are equal.

Two quantities are experimentally equal if we subtract them and zero is in the range of the difference.

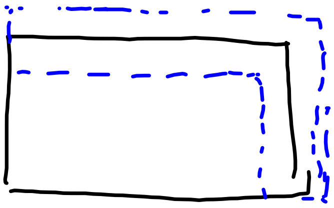
$3.1 \pm 0.3\,cm - 3.0 \pm 0.2\,cm = 0.1 \pm 0.4\,cm$

we cannot assume these are different (the difference could be zero)

So we say they are experimentally equal

Multiplication and Division

$2.0 \pm 0.2m = a$



$b = 4.0 \pm 0.2m$

$Q = ab \qquad \delta Q = ?$

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

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

$$= \sqrt{\left(\frac{0.2m}{2.0m}\right)^2 + \left(\frac{0.2m}{4.0m}\right)^2}$$

$$\frac{\delta Q}{8.0m^2} = 0.04$$

$$\delta Q = 0.3m^2$$

$$Q = ab = (2.0m)(4.0m) = 8.0m^2$$

$$Q = 8.0 \pm 0.3m^2$$

$$Q = \frac{b}{a} = \frac{4.0 \pm 0.2m}{2.0 \pm 0.2m} = 2.0 \pm 0.08$$

$\frac{\delta Q}{|Q|} = 0.04$ as before

$$\frac{\delta Q}{2.0} = 0.04$$

$$\delta Q = 0.08$$

$Q = 2.00 \pm 0.08$

$Q = 2.0 \pm 0.1$ ← 1 digit

Nastier functions...

$\sin(30^\circ \pm 0.1^\circ)$ = this requires calculus to do this properly

We will use WCS (worst case scenario)

$\sin 30.1^\circ = 0.502$
$\sin 30.0^\circ = 0.500$
$\sin 29.9^\circ = 0.498$

So $\sin(30.0 \pm 0.1^\circ)$

$= 0.500 \pm 0.002$