Forces in Equilibrium

# Goals

To practice solving force problems and comparing with the results of a real experiment.

# Equipment

* Force board
* Set of masses with hooks
* Two 20-N spring scales
* String with three or four loops
* Protractor

# Experiment

## Setup

1. Calibrate the spring scales.
2. Then hook them through two loops of the string, leaving one loop in between to hang a mass.
3. Hang the other ends of the spring scales to hooks in the force board frame.
4. Hang a 1-kg mass from the middle loop on the string. The mass should be hanging from the string and not resting on anything else. If this isn’t true, adjust the location of the spring scales.

## Measurement

Record the weight of the hanging mass. Also record the directions of the left and right strings as angles using a protractor. (I suggest measuring the angles from the vertical.) Record also the tension in each string as reported by the spring scales.

Record all this data into an Excel spreadsheet that you can copy and paste to embed into your lab report.

## Analysis

The system we are considering is of the center knot of the string, with the tension left and right and downward toward the hanging weight are all considered external forces.



Analyze the system in the following two different ways:

### Analysis 1: Calculate the net force vector

All forces are known, either from the reading on the spring scales or because of the known weight. Measure the angles of each string from the vertical using a protractor, and then use trigonometry to calculate the x and y components of the different forces. Calculate the net force vector on the center knot. Record the x and y component of net force into your data table. What should this net force be? How closely did your experimental result agree with your prediction? Are they as close as expected, taking into account measurement error? As a good starting point, you can consider the error in the sum of forces to be about the same as the measurement error of a single force measurement. (If you are interested, I can show you how to propagate error to find a more exact measurement.) If results agree with your prediction within expected error, you may go on; otherwise, ask for help, as perhaps your math is wrong somewhere.

### Analysis 2: Calculate the tension forces

For this second analysis, treat the tensions in the left and right strings is unknown. The hanging weight and the angles of the strings are known. Using Newton’s Second Law, and the fact that the acceleration is zero, solve for the tensions in the left and right strings. Compare your answer to the measured tension from the spring scales. Are your answers close enough for you to consider that your analytical calculation has been validated by the experimental result? (If not, why not? Look for where there might be an error.)

These calculations may be made easier and more automatic by the use of Excel formulas.

## Multiple trials

Change the location of the spring scales to produce additional trials, for a total of three different trials. Try to go for the following scenarios:

1. The left and right tensions are nearly equal.
2. One tension is much greater than the other.
3. One string is angled so much that its spring scale is lower than the center knot.

# Conclusion

Present your results neatly and answer the questions where you discuss differences between your calculated and measured results (highlighted). Also, discuss what you learned when trying to recreate the scenarios as described.

Finally, upload this file to the Canvas assignment. Thanks!