# INTRODUCTION

One purpose of this lab course is to develop your ability to communicate technical data through written documents. To that end, you will be required to write a lab report for each lab of the semester. A lab report is a self contained description of the experiment being performed, including the motivation for performing the experiment, the data collected, sample calculations and an analysis based on the data that addresses the motivation for performing the experiment. Since measurements are never exact, it is also necessary to include an estimate of the experimental uncertainty in the measurements, which should be considered whenever comparing measured results.

The method in which the data and other content of the lab report is also important. All numerical values should be written with the proper number of significant figures that reflect the uncertainty of the value. Additionally, all numerical values for data must include the appropriate units.

Beyond the content of the lab report, a well written lab report should adhere to a set of style guidelines which include the following: The text of the report should not contain incomplete sentences or other basic grammatical errors. The report should not be written in the first person. Passive voice is preferred. Your lab instructor may have further comments on appropriate style.

The following two example lab reports show a poorly written report and a well written report for a fictitious lab. Both use the same set of data and both are about the same length. Compare and contrast these two reports. Which of these two reports more clearly communicates the meaning and results of the lab? How many examples of bad style can you find in the poorly written report?

# Example of a poorly written lab report

## Objective

In this lab we will use weights hanging off a string to calibrate the response of a torsion pendulum. Then we will put a 10kg and a 20kg weight next to the torsion pendulum and measure its deflection when the weights are 10cm and 20cm apart. We will plot the value for $m_1m_2/r^2$ versus force and use the graph to determine the value for G.

## Data

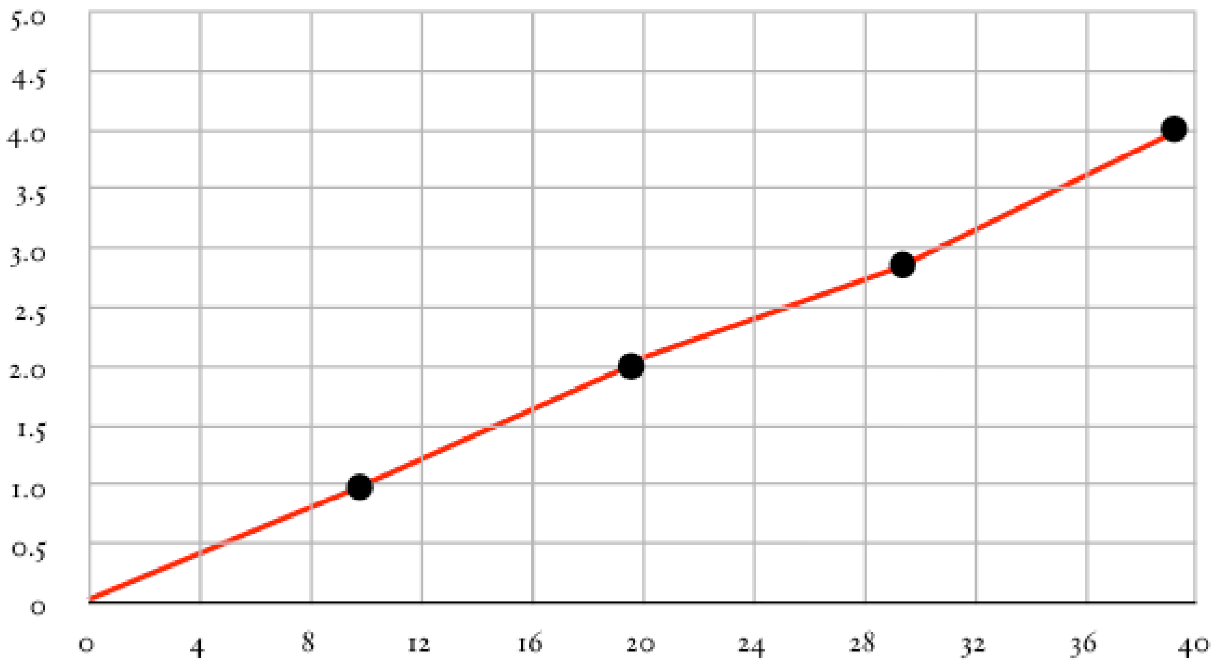
displacement vs. force calibration

| Trial | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Hanging mass | 1 | 2 | 3 | 4 |
| Tension | $9.80 \times 10^{-3}$ | $19.6 \times 10^{-3}$ | $29.4 \times 10^{-3}$ | $39.2 \times 10^{-3}$ |
| Angular Displacement | 0.99 | 2.01 | 2.87 | 4.02 |

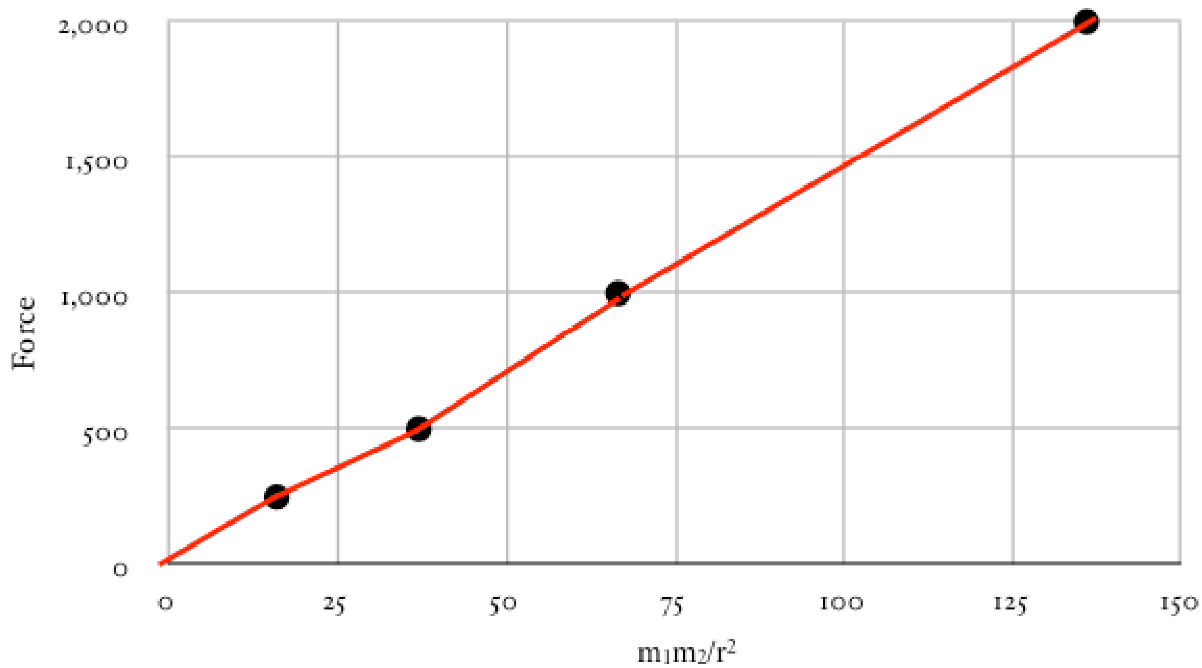
gravitational force measurements

| Trial | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Test mass | 10 kg | 10 kg | 20 kg | 20 kg |
| Separation | 10 cm | 20 cm | 10 cm | 20 cm |
| Angular Displacement | 6.81 nrad | 1.65 nrad | 13.9 nrad | 3.8 nrad |
| Force | 66.7102 nN | 16.1958 nN | 136.1004 nN | 37.1697 nN |

Graph 1




Graph 2




*Example of a Poorly Written Lab Report*

## Analysis

We measured a value of G that was $6.27 \times 10^{-11}$, which is pretty close to the accepted value of $6.67 \times 10^{-11}$. The percent error is

$$\left| \frac{6.67 - 6.27}{6.67} \right| = 0.06$$

The reason for the difference was probably due to a mistake that we made measuring the distance between the masses. If we had been more careful we probably could have measured it better. Also another source of error was friction in the string and our equipment was kind of old.

# Example of a well written lab report

## Objective:

Newton's law of gravitation describes the gravitational force between massive objects. The evolution of the universe, the motion of the planets, and even the behavior of everyday object can be explained using Newton's equation for the gravitational force,

$$\vec{F} = -G\frac{m_1 m_2}{r_{12}^2}\hat{r}$$

which says the gravitational force between two objects is directly proportional to the mass of the objects and inversely proportional to their separation squared. Knowledge of the value of the constant of proportionality, G (called the universal gravitational constant), is fundamental to being able to apply this equation, and was experimentally measured in this lab.

## Experimental Method

A "torsional pendulum" was used as a tool for measuring the force of attraction between two pairs of massive objects. The torsional pendulum consists of barbell like structure with 1kg masses on either end of a 30cm rod of negligible mass. The structure is suspended from its center of mass by a thin wire of length 1m, and the angle of the structure in the horizontal plane is measured using capacitive sensors.

The angular displacement of the torsional pendulum caused by a given torque is calibrated by attaching a string to each end of the barbell and running it over a pulley on the edge of the table so that a mass hanging off the string can supply a known tension to the string, while the change in angular displacement is recorded.

Once the torsional pendulum is calibrated, a pair of large test-masses is placed closed to the ends of the barbell so that the gravitational force between each of the masses and each end of the barbell causes a rotation of the torsional pendulum that can be measured to determine the gravitational force. For various mass test-masses and test-mass–barbell separations the gravitational force is measured and the value. The value of G is determined from the slope of a plot of force versus $m_1 m_2/r^2_{12}$.

# Data

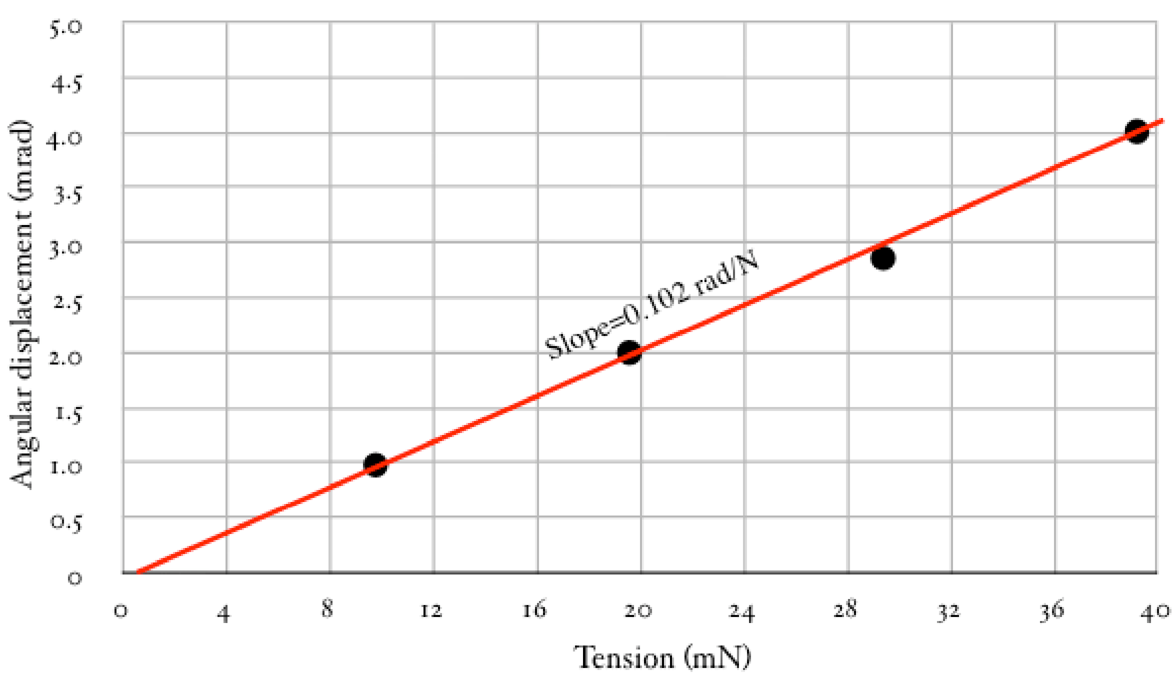
displacement vs. force calibration

| Trial | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Hanging mass | 1.00 g | 2.00 g | 3.00 g | 4.00 g |
| Tension | $9.80 \times 10^{-3}$ N | $19.6 \times 10^{-3}$ N | $29.4 \times 10^{-3}$ N | $39.2 \times 10^{-3}$ N |
| Angular Displacement | 0.99 mrad | 2.01 mrad | 2.87 mrad | 4.02 mrad |

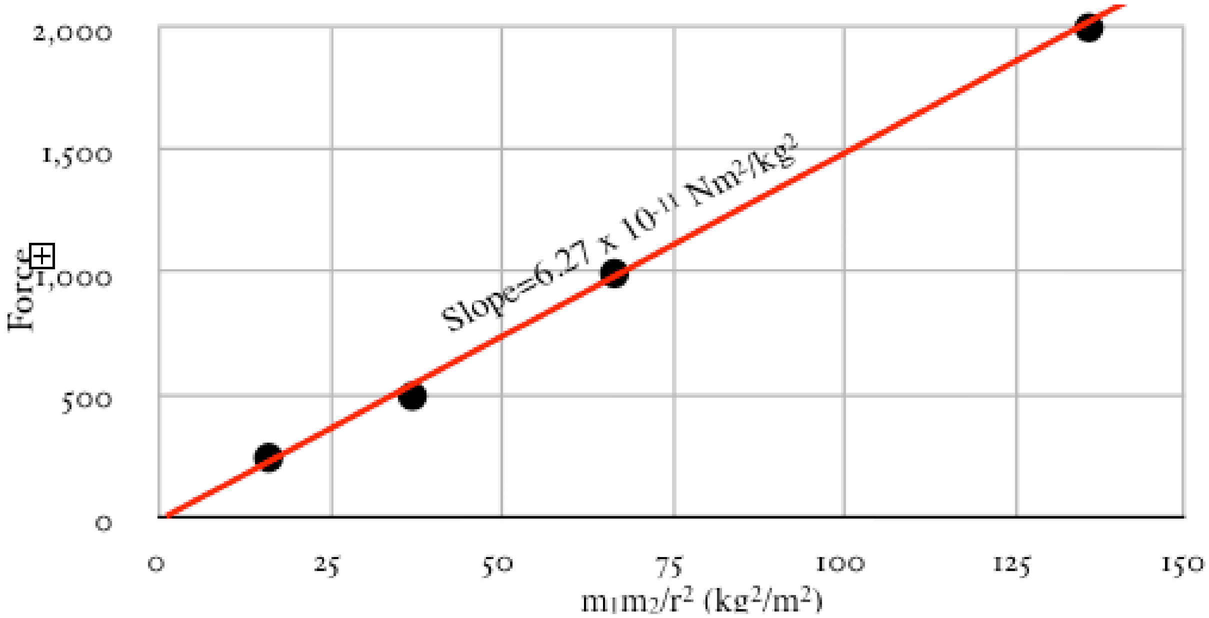
gravitational force measurements

| Trial | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Test mass | 10.0 kg | 10.0 kg | 20.0 kg | 20.0 kg |
| Separation | 10.0 cm | 20.0 cm | 10.0 cm | 20.0 cm |
| Angular Displacement | 6.81 nrad | 1.65 nrad | 13.9 nrad | 3.80 nrad |
| Force | 66.7 nN | 16.2 nN | 136 nN | 37.2 nN |

Calibration curve



Force vs displacement measurements




# Analysis

The torsional pendulum was found to have a rotation of 0.102 rad per Newton of force acting on each of the barbell masses. The calibrated response of the torsional pendulum was used to determine the force producing the measured angular displacement of the pendulum for 4 different combinations of test masses and test mass positions. When $m_1m_2/r^2$ is plotted versus the measured force for each case the slope of the best-fit line is G. The uncertainty is dominated by the uncertainty in r. The distance between the test mass and the barbell was measured with a meter stick, and uncertainty in determining the center-of-mass position from which to measure the distance is approximately 1cm, thus the fraction uncertainty in r for r=10cm is _r/r=0.1, and the fractional uncertainty in $m_1m_2/r^2$ is 2_r/r=0.2. Having average 4 data points the fractional uncertainty in the average is reduced by √4, giving a fractional uncertainty in G of 0.1. Thus from the slope of the best-fit curve the value of G was found to be 6.27±0.67 x $10^{-11}$ $Nm^2/kg^{2.}$

Comparing the measured value for G to the accepted value $G_{acc}$=6.67 x $10^{-11}$ $Nm^2/kg^2$ we see our percent error is

$$\left|\frac{6.67 - 6.27}{6.67}\right| \times 100\% = 6\%$$

which is within the experimental uncertainty of this measurement, therefore the measured value of G, the universal gravitational constant, agrees with the accepted value