PHYSICS 110, Lab 1, Part 1

# Analysis Worksheet

1. Include a photo of your setup that shows a location of your coin/small object and your ruler/measuring tape in place for measuring the location.

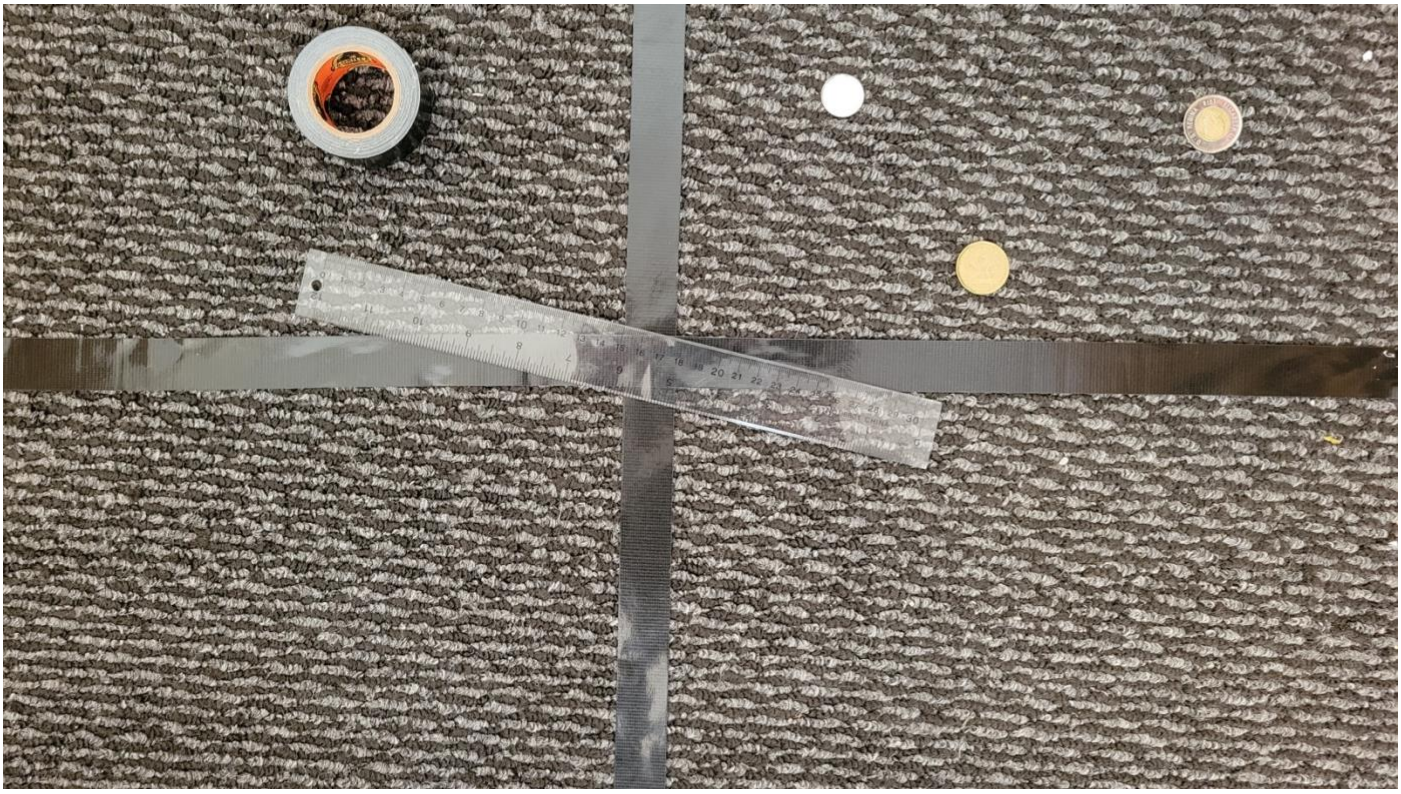


**Figure: Transparent ruler, tape, 3 coins for 8 trials.**

2. Include a table of your values with columns for grouping / set (1-8), trial (1- 10), *x* and *y* positions.

| Set | Trial | X (cm) | Y (cm) |
|---|---|---|---|
| 1 | 1 | 13.5 | -24.1 |
| 1 | 2 | 2.4 | 21.3 |
| 1 | 3 | -21.1 | 17.6 |
| 1 | 4 | 22.0 | -10.1 |
| 1 | 5 | 23.6 | -0.9 |
| 1 | 6 | -9.5 | -25.3 |
| 1 | 7 | -15.8 | 3.8 |
| 1 | 8 | 17.7 | 24.1 |
| 1 | 9 | 14.0 | 8.3 |
| 1 | 10 | -9.0 | 9.5 |

| Set | Trial | X (cm) | Y (cm) |
|---|---|---|---|
| 2 | 1 | 25.1 | 3.2 |
| 2 | 2 | -24.9 | 2.2 |
| 2 | 3 | 2.6 | 7.7 |
| 2 | 4 | 7.4 | -8.5 |
| 2 | 5 | 0.8 | 24.5 |
| 2 | 6 | -28.0 | -8.9 |
| 2 | 7 | -16.6 | -8.1 |
| 2 | 8 | -2.3 | -1.5 |
| 2 | 9 | -4.3 | 16.2 |
| 2 | 10 | -18.6 | 28.7 |

| Set | Trial | X (cm) | Y (cm) |
|---|---|---|---|
| 3 | 1 | 18.4 | 11.1 |
| 3 | 2 | 2.6 | 9.6 |
| 3 | 3 | -8.9 | 6.2 |
| 3 | 4 | 29.5 | 28.3 |
| 3 | 5 | -2.7 | 26.5 |
| 3 | 6 | -7.3 | 14.6 |
| 3 | 7 | -6.0 | 4.0 |
| 3 | 8 | 3.5 | -1.6 |
| 3 | 9 | -18.5 | -6.2 |
| 3 | 10 | 11.4 | -2.1 |

| Set | Trial | X (cm) | Y (cm) |
|---|---|---|---|
| 6 | 1 | -9.9 | -7.3 |
| 6 | 2 | 25.2 | -18.7 |
| 6 | 3 | 14.2 | -6.0 |
| 6 | 4 | 27.8 | 20.8 |
| 6 | 5 | -3.0 | -29.4 |
| 6 | 6 | 7.3 | -5.7 |
| 6 | 7 | 12.5 | 2.0 |
| 6 | 8 | -21.9 | 1.6 |
| 6 | 9 | -29.8 | 14.9 |
| 6 | 10 | 3.4 | 19.0 |

| Set | Trial | X (cm) | Y (cm) |
|---|---|---|---|
| 4 | 1 | 5.67 | 19.0 |
| 4 | 2 | 7.54 | -25.0 |
| 4 | 3 | -2.88 | -8.7 |
| 4 | 4 | 7.31 | 21.1 |
| 4 | 5 | 5.10 | -14.8 |
| 4 | 6 | -0.65 | 1.8 |
| 4 | 7 | 8.67 | -2.2 |
| 4 | 8 | 15.03 | 28.2 |
| 4 | 9 | 9.93 | 19.2 |
| 4 | 10 | 0.21 | 7.3 |

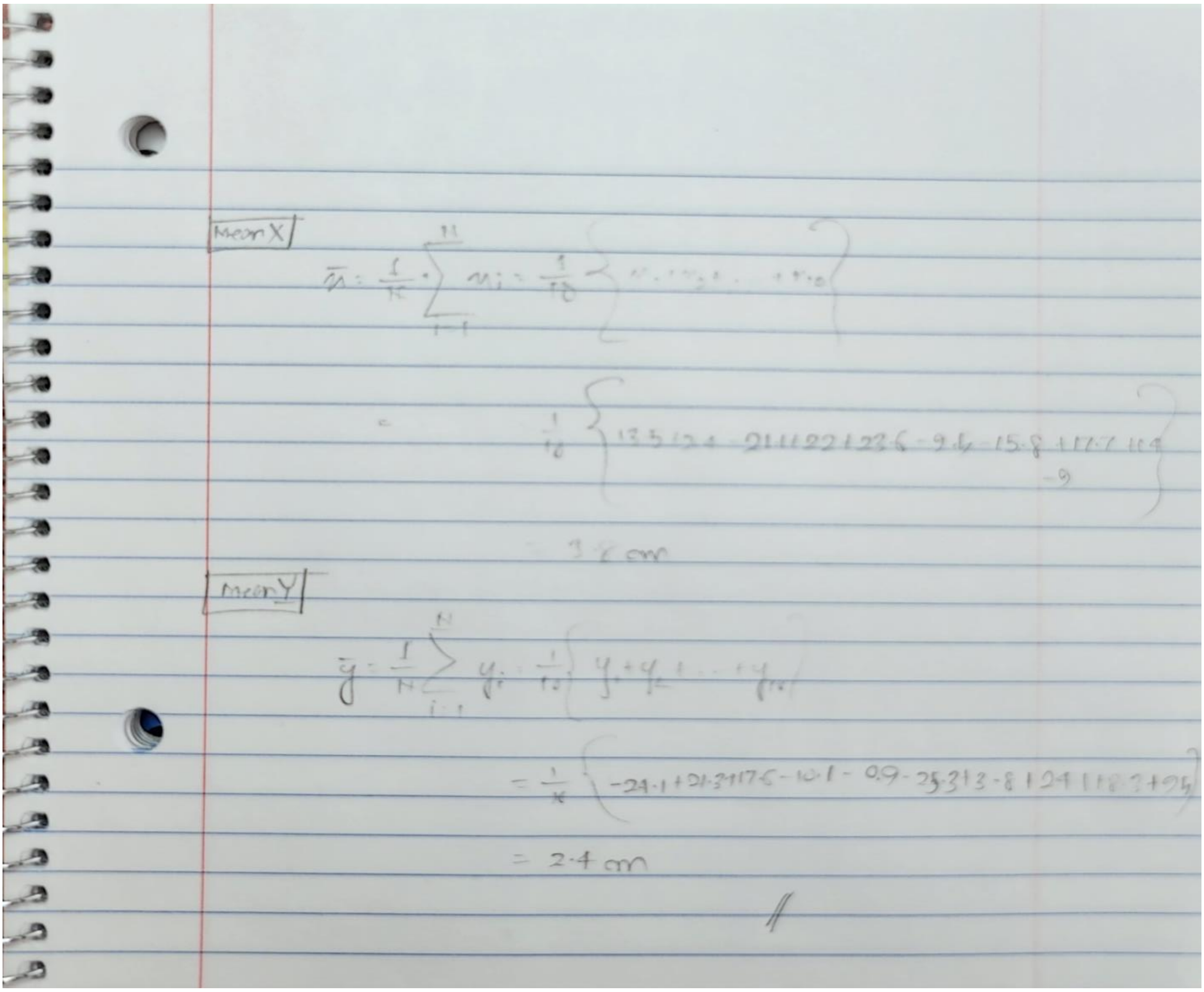
| Set | Trial | X (cm) | Y (cm) |
|---|---|---|---|
| 7 | 1 | -1.54 | -5.1 |
| 7 | 2 | 6.5 | 11.3 |
| 7 | 3 | -27.4 | 7.6 |
| 7 | 4 | 8.2 | -19.7 |
| 7 | 5 | -8.04 | -20.7 |
| 7 | 6 | 9.3 | -5.6 |
| 7 | 7 | 28.9 | -23.9 |
| 7 | 8 | -16.8 | -19.5 |
| 7 | 9 | 2.2 | -7.1 |
| 7 | 10 | 6.6 | 1.5 |

| Set | Trial | X (cm) | Y (cm) |
|---|---|---|---|
| 5 | 1 | -17.8 | 21.1 |
| 5 | 2 | 6.6 | 2.4 |
| 5 | 3 | 12.2 | -6.8 |
| 5 | 4 | -5.7 | -10.1 |
| 5 | 5 | 7.6 | -7.2 |
| 5 | 6 | -27.5 | 11.3 |
| 5 | 7 | -22.2 | 13.1 |
| 5 | 8 | -5.6 | -17.1 |
| 5 | 9 | -0.9 | 29.0 |
| 5 | 10 | 29.6 | 18.7 |

| Set | Trial | X (cm) | Y (cm) |
|---|---|---|---|
| 8 | 1 | -24.6 | 15.3 |
| 8 | 2 | 24.5 | -23.5 |
| 8 | 3 | -12.0 | 6.5 |
| 8 | 4 | 23.9 | -27.4 |
| 8 | 5 | -29.6 | 8.2 |
| 8 | 6 | -25.2 | 27.1 |
| 8 | 7 | 2.2 | 9.3 |
| 8 | 8 | 2.7 | 28.9 |
| 8 | 9 | 25.6 | -16.8 |
| 8 | 10 | 10.8 | -13.7 |

3. Determine the mean value of the *x* and *y* locations for one of the groups/sets of trials. Show your work.

| Set | Trial | X (cm) | Y (cm) | | Mean X (cm) | Mean Y (cm) | (Data - Mean)^2 X (cm) | Standard Deviation of X (cm) | Standard Deviation of Mean of X (cm) | | SD1 Y (cm) | Standard Deviation of Y (cm) | Standard Deviation of Mean of Y (cm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 13.5 | -24.1 | | | | 94.8877 | | | | 705.3608 | | |
| 1 | 2 | 2.4 | 21.3 | | | | 1.9600 | | | | 357.9099 | | |
| 1 | 3 | -21.1 | 17.6 | | | | 619.8388 | | | | 229.8995 | | |
| 1 | 4 | 22.0 | -10.1 | | | | 331.8591 | | | | 157.1580 | | |
| 1 | 5 | 23.6 | -0.9 | | | | 392.3310 | | | | 11.0001 | | |
| 1 | 6 | -9.5 | -25.3 | | | | 176.3656 | | | | 769.6590 | | |
| 1 | 7 | -15.8 | 3.8 | | | | 381.8597 | | | | 1.9168 | | |
| 1 | 8 | 17.7 | 24.1 | | | | 192.9499 | | | | 471.7244 | | |
| 1 | 9 | 14.0 | 8.3 | | | | 103.8923 | | | | 35.0153 | | |
| 1 | 10 | -9.0 | 9.5 | | 3.8 | 2.4 | 162.0709 | 16.53 | 5.23 | | 49.7342 | 17.60 | 5.567143622 |



Mean X

$$\bar{x} = \frac{1}{N}\sum_{i=1}^{N} x_i = \frac{1}{10}\{x_1 + x_2 + \dots + x_{10}\}$$

$$= \frac{1}{10}\{13.5 + 2.4 - 21.1 + 22 + 23.6 - 9.6 - 15.8 + 17.7 + 14 - 9\}$$

$$= 3.8 \text{ cm}$$

Mean Y

$$\bar{y} = \frac{1}{N}\sum_{i=1}^{N} y_i = \frac{1}{10}\{y_1 + y_2 + \dots + y_{10}\}$$

$$= \frac{1}{10}\{-24.1 + 21.3 + 17.6 - 10.1 - 0.9 - 25.3 + 3.8 + 24.1 + 8.3 + 9.5\}$$

$$= 2.4 \text{ cm}$$

// All values used are in Centimeter Unit.

**Figure: Mean data Calculation of x and y.**

4. Determine the standard deviation (σ) of the *x* and *y* locations for one of the sets of data. Show your work.

| Set | Trial | X (cm) | Y (cm) | | Mean X (cm) | Mean Y (cm) | (Data - Mean)^2 X (cm) | Standard Deviation of X (cm) | Standard Deviation of Mean of X (cm) | | SD1 Y (cm) | Standard Deviation of Y (cm) | Standard Deviation of Mean of Y (cm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 13.5 | -24.1 | | | | 94.8877 | | | | 705.3608 | | |
| 1 | 2 | 2.4 | 21.3 | | | | 1.9600 | | | | 357.9099 | | |
| 1 | 3 | -21.1 | 17.6 | | | | 619.8388 | | | | 229.8995 | | |
| 1 | 4 | 22.0 | -10.1 | | | | 331.8591 | | | | 157.1580 | | |
| 1 | 5 | 23.6 | -0.9 | | | | 392.3310 | | | | 11.0001 | | |
| 1 | 6 | -9.5 | -25.3 | | | | 176.3656 | | | | 769.6590 | | |
| 1 | 7 | -15.8 | 3.8 | | | | 381.8597 | | | | 1.9168 | | |
| 1 | 8 | 17.7 | 24.1 | | | | 192.9499 | | | | 471.7244 | | |
| 1 | 9 | 14.0 | 8.3 | | | | 103.8923 | | | | 35.0153 | | |
| 1 | 10 | -9.0 | 9.5 | | 3.8 | 2.4 | 162.0709 | 16.53 | 5.23 | | 49.7342 | 17.60 | 5.567143622 |

// All values used are in Centimeter Unit.

(Answer in next page)

**Standard Deviation X**

$$\sigma_x = \left.\sqrt{\frac{\sum_{i=1}^{N}(x_i-\bar{x})^2}{N-1}}\,\right|_{N=10} = \sqrt{\frac{(x_1-\bar{x})^2+(x_2-\bar{x})^2+(x_3-\bar{x})^2+\dots+(x_{10}-\bar{x})^2}{9}}$$

$$= \sqrt{\frac{94.9+1.9+619.8+331.8+392.3+1176.4+381.8+192.9+103.9+162.07}{9}}$$

$$= 16.53$$

**Standard Deviation Y**

$$\sigma_y = \left.\sqrt{\frac{\sum_{i=1}^{N}(y_i-\bar{y})^2}{N-1}}\,\right|_{N=10} = \sqrt{\frac{(y_1-\bar{y})^2+(y_2-\bar{y})^2+(y_3-\bar{y})^2+\dots+(y_{10}-\bar{y})^2}{9}}$$

$$= \sqrt{\frac{705.3+357.9+229.8+157.2+11.001+769.65+1.916+471.724+35.01+619.77}{9}}$$

$$= 17.6$$

**Figure: Standard Deviation (σ) of the *x* and *y* locations.**

5. Estimate the *standard deviation of the mean* ($\delta$) of the $x$ and $y$ location. Show your work.

// All values used are in Centimeter Unit.

$\boxed{\text{Standard Deviation of mean X}}$

$\sigma_x = 16.53$

$N = 10$

$$\sigma_{\bar{x}} \approx \sigma_x / \sqrt{N}$$

$$\approx \frac{16.53}{\sqrt{10}}$$

$$\approx 5.23 \text{ cm}$$

$\boxed{\text{Standard Deviation of mean Y}}$

$\sigma_y = 17.6$

$N = \sqrt{10}$

$$\sigma_{\bar{y}} \approx \sigma_y / \sqrt{N}$$

$$\approx \frac{17.6}{\sqrt{10}}$$

$$\approx 5.56 \text{ cm}$$

**Figure:** ***Standard Deviation of the mean*** **($\delta$) of the** ***x*** **and** ***y*** **location.**

6. Respond to the following questions/instructions:

1. (a) How could you improve the precision of this experiment using reason- ably priced/accessible equipment?
   In this experiment, I used a transparent ruler, a tape, and several coins. I think using a ruler and a tape, in terms of accessibility is as accessible as the experiment can be. To improve the precision, I believe (from the lessons in the experiment) that using a **2-dollar coin** is a good and effective use of a throwing non-rolling object, as to my experience, it's heavier than other types of coins and does not bounce back or hit walls when being thrown.

2. (b) How could you improve the accuracy of this experiment using reasonably priced/accessible equipment?
   To improve the accuracy of the experiment with the use of a transparent ruler, a tape, and several coins – I think choosing a levelled ground is also important. I used a carpet in some of the trials in my experiment, which resulted in the coins used to not bounce back and forth. But I also used the floor as a levelled ground for some of the trials. In doing so, I realized the results of the experiment largely depends on the type of grounds being used as well. So, specifying what kind of floor one should prioritize for an experiment like this can improve the accuracy as well.

3. (c) Why is the mean value used to represent the aim?
   The mean value is used to measure how much closer to the origin, the aim was in average in all the trials (throws). For my first trial, it came out to be in the first quadrant of the set (+3.8, +2.4). However, adding the data from other trials will give us slightly different values, as we were aiming for the origin. Trial 1 shows the aim was in average, 3.8 cm from the x direction and 2.4 cm from the y direction.

4. (d) Sometimes a percentage precision (e.g., $\delta_X / \bar{x}$) is quoted in scientific publications. Why would this not be a good method for quoting the precision of the aim? (Hint: Consider what happens as the aim gets worse.)

As the aim gets worse, the standard deviation of the data (x and y positions of the coins) tells us how much deviated the data can be from the given values. Standard Deviation of the mean of x and y positions tells us how much deviated the data can be from the mean of the positions. This helps us identify the accuracy of the aim, and help us measure, and take decisions based on the learnings from these experiments. Therefore, it’s important to show all the data to
give a complete picture of the experiment (data x, data y, mean of x, mean of y, standard deviation of x, standard deviation of y, standard deviation of the mean of x, standard deviation of the mean of y).