Range vs. Height

1 Uncertainty and error bars

As you take more measurements, you will see that the running average fluctuates wildly at first, but then starts to settle down. This is a pattern we see in physical measurements all the time. There will always be uncertainty in our experiments due to imperfections in our apparatus. However, data in general will tend to cluster around the 'true' value of the parameter that is being measured.

As an example, consider Figure [1].

The *standard deviation* of the data tells us how precise our measurements are. This is a measure of the spread of the data. Formally, the standard deviation σ is given by

$$\sigma = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(x_i - \mu)}$$

where n is the number of data points (measurements), and μ is their average (mean).

Most data obtained in the real world follows a pattern known as the *normal distribution*. You may have heard it being referred to as the 'bell curve'. You can see the bell curve forming in Figure [1] as well. For such distributions, 68.3% of the values lie within one standard deviation of the mean.

If we approximate 68.2% as 66.6% (and this is not such an outlandish thing to do), we can say that 2/3rds of the data lies within one standard deviation of the mean. For this lab, that is exactly what we are going to do - we will take 18 measurements (This is a good number because it is a multiple of 6), consider the highest 3 and the lowest 3 to be outliers, and get the error bars by dividing the range of the middle 12 measurements by 2. See Figure [3] for an example.

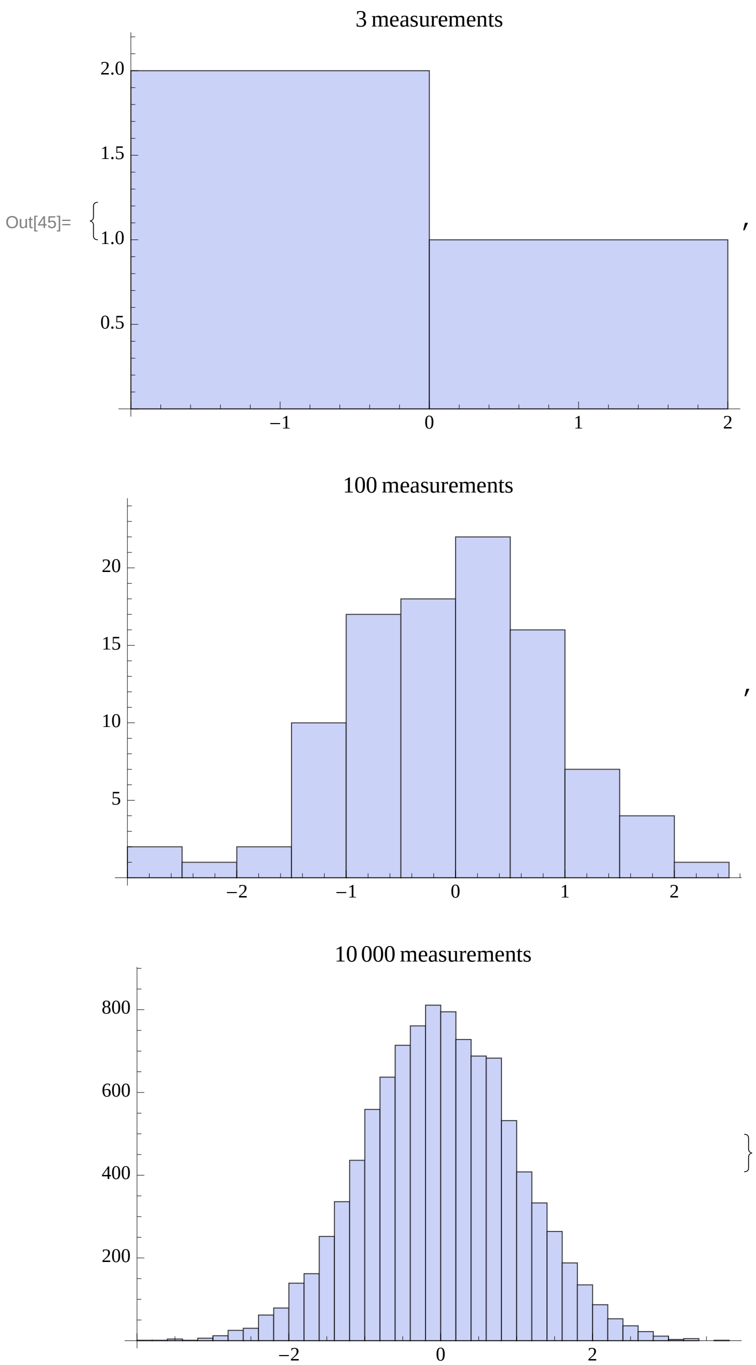

Figure 1: We can see that as we take a larger number of measurements, we come closer to the 'real' value, and also discover how precise our apparatus is.

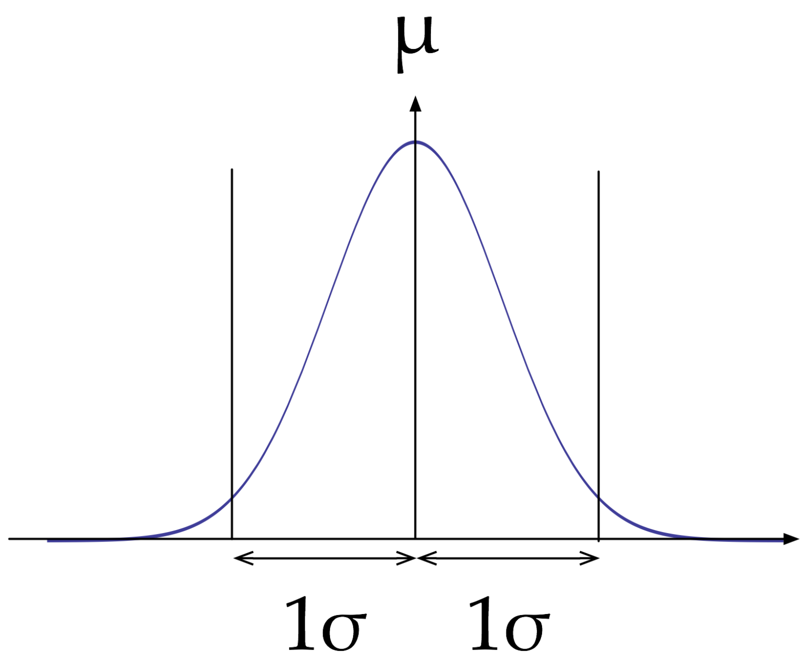

Figure 2: The majority of the data lies within one standard deviation of the mean.

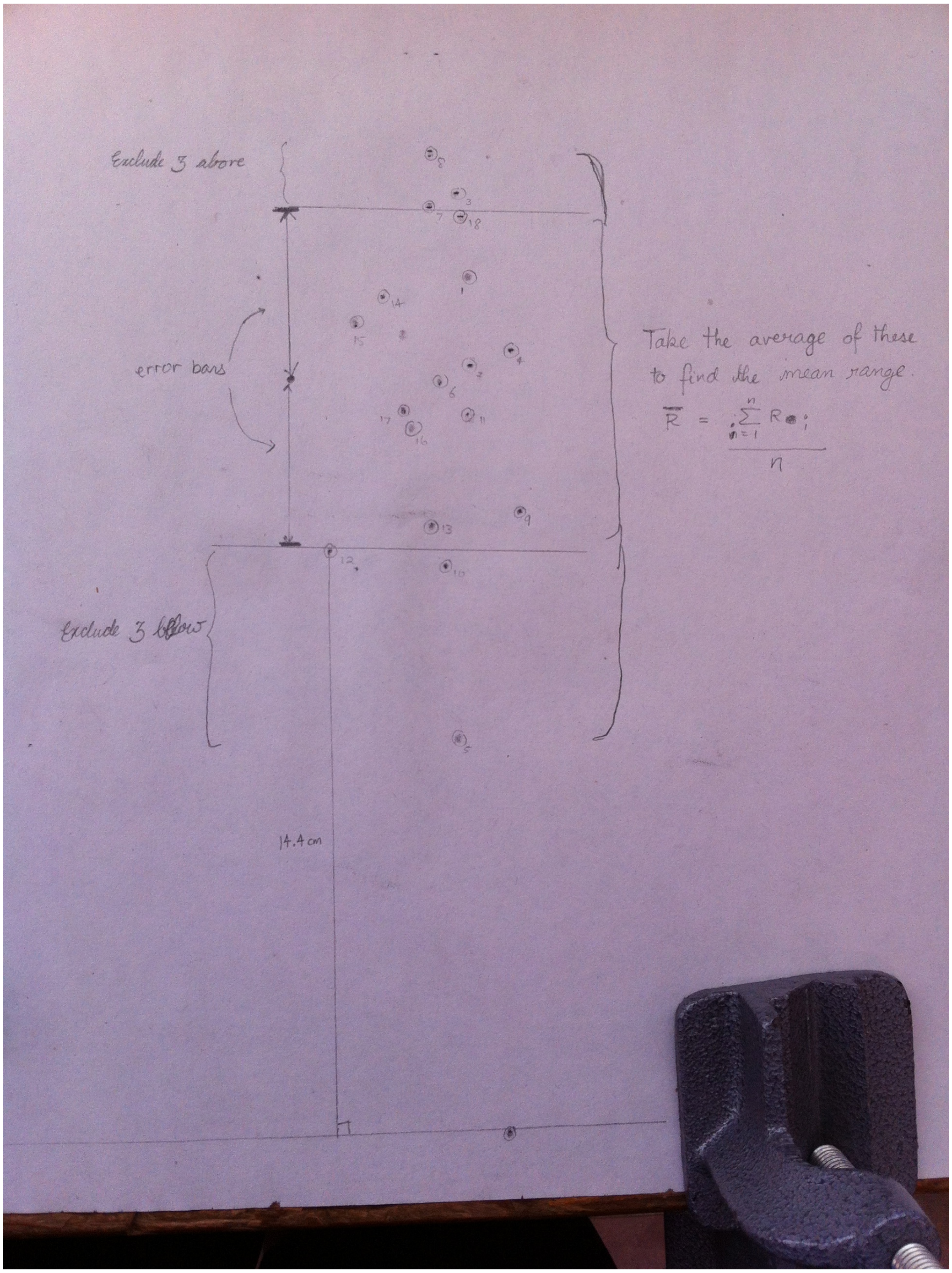

Figure 3: An example

2 How to find R(H,h)

Just follow the steps below and use the kinematic equations you have learned. (And come to the consultation room in PAS 372 if you have any questions!)

1. Find the velocity of the ball just before it hits the bounce plate, assuming it starts from rest from the drop plate.

2. Take this velocity to be the initial horizontal velocity of the ball just after it bounces, and assume that there is no vertical velocity after the bounce.

3. Find the time the ball takes to travel a distance h in the vertical direction (consider the motion in the vertical and horizontal directions separately). Remember that the force of gravity acts downwards on the ball.

4. Find the distance that the ball travels horizontally, using the initial horizontal velocity you found in step 2 and the time you found in step 3.

5. This is your range, R.

Check your final answer. You should have obtained

$$R(H,h) = 2\sqrt{hH}$$