# Lab 01: Data Analysis I Uncertainty in Calculations with Measured Quantities

### **Objective**

To estimate the uncertainty in result of calculation with measured quantities.

## **Introduction**

When you measure something, there is always an uncertainty in the measurement. For example, if you want to measure the length of the rectangle shown in the figure below, you probably estimate that the length *l* should be between 5.23 to 5.25 cm. You can express this by writing  $l = 5.24 \pm 0.01$  cm. We call 5.24 the most probable value and we use symbol  $l_0$  for it. We call 0.01 the uncertainty or the error in the measurement and we use symbol  $\Delta l$  for it. So, we can write our measurement in a symbolic form as  $l = l_0 \pm \Delta l$ . The relative error in the measurement of the length is  $\Delta l/l_0 = 0.01/5.24 = 0.002$ . The percent error in the measurement of the length is  $(\Delta l/l_0) \times 100\% = 0.2\%$ .



Fig. 1. Measuring a length of a rectangle

Since the error in a measurement is an estimation, we need only to use one or at most two significant digits to express it. Similarly, when you report the relative error or percent error of a measurement, you should use one or two significant digits. But if the error or relative error involves intermediate calculation steps, we may keep two or three significant digits for the purpose of the calculation. When reporting a measurement, the most probable value and the error should have the same precision. The table below shows some examples.

Table 1.	Examp	oles or	1 how	to re	port measu	rements a	and their	errors.
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Mistake	Correction	Reason
$5.24264 \pm 0.01325$	$5.24 \pm 0.01$	The error should have one or
		two significant digits.
$5.2426 \pm 0.01$	$5.24 \pm 0.01$	The most probable value and
		the error should have the same
		precision.
$5.24 \pm 0.0136$	$5.24 \pm 0.01$	The most probable value and
		the error should have the same
		precision
Relative error:	Relative error:	Relative error should have one
0.01/5.24 = 0.00191	0.01/5.24 = 0.002	or two significant digits.
Percent error:	Percent error:	Percent error should have one
$(0.01/5.24) \times 100\% = 0.191\%$	$(0.01/5.24) \times 100\% = 0.2\%$	or two significant digits.

Suppose you measure the width w of the rectangle and you estimate it between 2.05 and 2.07 cm. Fill the following table using  $w = w_0 \pm \Delta w$ .

	Symbol	Value and units
The most probable value	<i>w</i> <sub>0</sub>	
The error		
The relative error		
The percent error		

In the following, we will estimate the resultant error when the measurements of the length l and width w are combined in an arithmetic operation such as addition or multiplication. We will use the function f(l, w) to represent this operation. The resultant error  $\Delta f$  can be estimated from the minimum and maximum possible deviations of f as follows.

$$\Delta f = \frac{f_{max} - f_{min}}{2} \tag{1}$$

## Addition and subtraction of measurements

**<u>Rule 1:</u>** The resultant error in adding or subtracting two measurements is the sum of the errors of the individual measurement.

 $\begin{array}{ccc} f = l + w & \rightarrow & \Delta f = \Delta l + \Delta w \\ f = l - w & \rightarrow & \Delta f = \Delta l + \Delta w \end{array}$ 

## Example 1:

Let  $l = 30.2 \pm 0.2$  and  $w = 10.3 \pm 0.1$ , find l + w and l - w. Answer 1:  $l + w = (30.2 + 10.3) \pm (0.2 + 0.1) = 40.5 \pm 0.3$  $l - w = (30.2 - 10.3) \pm (0.2 + 0.1) = 19.9 \pm 0.3$ 

**Exercise 2:** 

Let  $l = 70.5 \pm 0.3$  and  $w = 15.1 \pm 0.2$ , find l + w and l - w.

Justification for Rule 1:
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For addition $f = l + w$ ,
The maximum possible value of f is $f_{max} = l_0 + \Delta l + w_0 + \Delta w$
The minimum possible value of f is $f_{min} = l_0 - \Delta l + w_0 - \Delta w$
$\Delta f = \frac{f_{max} - f_{min}}{2} = \Delta l + \Delta w$
For subtraction $f = l - w$ ,
The maximum possible value of f is $f_{max} = l_0 + \Delta l - (w_0 - \Delta w)$
The minimum possible value of f is $f_{min} = l_0 - \Delta l - (w_0 + \Delta w)$
$\Delta f = \frac{f_{max} - f_{min}}{2} = \Delta l + \Delta w$

# Multiplication of a measurement with a constant

**<u>Rule 2</u>**: The resultant error when a measurement l is multiplied by a constant c is the product of the constant and the error of the measurement.

 $f = c l \qquad \rightarrow \qquad \Delta f = |c|\Delta l$ 

# Example 2:

Let  $l = 41.3 \pm 0.3$  and c = 2.351, find cl.

Answer 2:

 $cl_0 = 97.096$   $c\Delta l = 0.705$   $cl = 97.1 \pm 0.7$ You need to kee

You need to keep one or two significant digits in the error, and you need to make the precision of the most probable value and the error the same.

# **Exercise 3:**

Let  $l = 70.5 \pm 0.4$  and  $c = \pi$ , find *cl*.

Justification for Rule 2:	
For $c > 0$ ,	
The maximum possible value of $f$ is	$s  f_{max} = c(l_0 + \Delta l)$
The minimum possible value of $f$ is	$f_{min} = c(l_0 - \Delta l)$
	$\Delta f = \frac{f_{max} - f_{min}}{2} = c\Delta l$
For $c < 0$ ,	
The maximum possible value of $f$ is	$s  f_{max} = c(l_0 - \Delta l)$
The minimum possible value of $f$ is	$f_{min} = c(l_0 + \Delta l)$
	$\Delta f = \frac{f_{max} - f_{min}}{f_{max} - f_{min}} = -c\Delta l$

# **Multiplication and division of measurements**

<u>**Rule 3:**</u> The resultant relative error when two measurements are multiplied or divided is the sum of the relative errors of the individual measurement.

f = lw	$\rightarrow$	$\frac{\Delta f}{f_{r}} = \frac{\Delta l}{l_{r}} + \frac{\Delta w}{w_{r}}$
f = l/w	$\rightarrow$	$\frac{\Delta f}{f_0} = \frac{\Delta l}{l_0} + \frac{\Delta w}{w_0}$

# Example 3:

Let  $l = 30.2 \pm 0.2$  and  $w = 10.3 \pm 0.1$ , find l w and l/w.

Answer 3:

$$\begin{split} l_0 w_0 &= 30.2 \times 10.3 = 311.06\\ \frac{\Delta(lw)}{l_0 w_0} &= \frac{\Delta l}{l_0} + \frac{\Delta w}{w_0} = \frac{0.2}{30.2} + \frac{0.1}{10.3} = 0.0163\\ \rightarrow \Delta(lw) &= 0.0163 \times l_0 w_0 = 0.0163 \times 311.06 = 5.08\\ lw &= 311 \pm 5 \end{split}$$

$$\begin{split} &l_0/w_0 = 30.2/10.3 = 2.932\\ &\frac{\Delta(l/w)}{l_0/w_0} = \frac{\Delta l}{l_0} + \frac{\Delta w}{w_0} = \frac{0.2}{30.2} + \frac{0.1}{10.3} = 0.0163\\ &\rightarrow \Delta(l/w) = 0.0163 \times (l_0/w_0) = 0.0163 \times 2.932 = 0.04788\\ &l/w = 2.93 \pm 0.05 \end{split}$$

Note that we use three significant digits to express the relative error, since it is used later in calculating the error.

### **Exercise 4:**

Let  $l = 3.52 \pm 0.04$  and  $w = 2.65 \pm 0.05$ , find l w and l/w.

# **Justification for Rule 3:**

For multiplication $f = lw$ ,
The maximum possible value of f is $f_{max} = (l_0 + \Delta l)(w_0 + \Delta w) = l_0 w_0 + w_0 \Delta l + l_0 \Delta w + \Delta l \Delta w$
The minimum possible value of f is $f_{min} = (l_0 - \Delta l)(w_0 - \Delta w) = l_0 w_0 - w_0 \Delta l - l_0 \Delta w + \Delta l \Delta w$
$\Delta f = \frac{f_{max} - f_{min}}{2} = w_0 \Delta l + l_0 \Delta w$
$\rightarrow \frac{\Delta f}{f_0} = \frac{w_0 \overline{\Delta} l}{l_0 w_0} + \frac{l_0 \Delta w}{l_0 w_0} = \frac{\Delta l}{l_0} + \frac{\Delta w}{w_0}$
For division $f = \frac{l}{w}$ ,
The maximum possible value of f is $f_{max} = \frac{l_0 + \Delta l}{w_0 - \Delta w}$
The minimum possible value of f is $f_{min} = \frac{\int_{0}^{0} -\Delta l}{\frac{l_0 -\Delta l}{w_0 + \Delta w}}$
$\Delta f = \frac{f_{max} - f_{min}}{2} = \frac{1}{2} \left( \frac{l_0 + \Delta l}{w_0 - \Delta w} - \frac{l_0 - \Delta l}{w_0 + \Delta w} \right) = \frac{w_0 \Delta l + l_0 \Delta w}{w_0^2 - \Delta w^2}$
We can ignore $\Delta w^2$ in the denominator since it is much smaller than $w_0^2 \rightarrow \Delta f \approx \frac{1}{w_0} \Delta l + \frac{l_0}{w_0^2} \Delta w$
$ \Delta f = \Delta l + l_0 \Delta w = \Delta l + \Delta w $
$\neg \frac{1}{f_0} - \frac{1}{w_0(l_0/w_0)} + \frac{1}{w_0^2(l_0/w_0)} - \frac{1}{l_0} + \frac{1}{w_0}$

## Raising a measurement to a power of constant value

**<u>Rule 4</u>**: The resultant relative error of raising a measurement to a power of constant value c is the absolute value of the constant multiplied by the relative errors of the measurement.  $f = l^c \qquad \rightarrow \qquad \frac{\Delta f}{f_0} = |c| \frac{\Delta l}{l_0}$ 

Example 4: Let  $l = 51.3 \pm 0.8$  and c = -0.5, find  $l^c$ . Answer 4:  $l_0^c = 51.3^{-0.5} = 0.1396$   $\frac{\Delta(l^c)}{l_0^c} = |c| \frac{\Delta l}{l_0} = 0.00780$   $\Delta(l^c) = l_0^c \times |c| \frac{\Delta l}{l_0} = 0.00109$  $l^c = 0.140 \pm 0.001$ 

**Exercise 5:** Let  $l = 51.3 \pm 0.8$  and c = 0.5, find  $l^c$ .

# Justification for Rule 4:

For c > 0,

The maximum possible value of $f$ is	$f_{max} = (l_0 + \Delta l)^c = l_0^c \left(1 + \frac{\Delta l}{l_0}\right)^c \approx l_0^c (1 + c\frac{\Delta l}{l_0})$
The minimum possible value of $f$ is	$f_{min} = (l_0 - \Delta l)^c = l_0^c \left(1 - \frac{\Delta l}{l_0}\right)^c \approx l_0^c (1 - c \frac{\Delta l}{l_0})$
	$\Delta f = \frac{f_{max} - f_{min}}{2} = l_0^c c \frac{\Delta l}{l_0}$
	$\rightarrow \frac{\Delta f}{\epsilon} = \frac{l_0^c c \frac{\Delta l}{l_0}}{l_0^c} = c \frac{\Delta l}{l_0^c}$
For $c < 0$ ,	$j_0$ $\iota_0$ $\iota_0$
The maximum possible value of $f$ is	$f_{max} = (l_0 - \Delta l)^c = l_0^c \left(1 - \frac{\Delta l}{l_0}\right)^c \approx l_0^c (1 - c\frac{\Delta l}{l_0})$

The minimum possible value of 
$$f$$
 is  $f_{min} = (l_0 + \Delta l)^c = l_0^c \left(1 + \frac{\Delta l}{l_0}\right)^c \approx l_0^c (1 + c \frac{\Delta l}{l_0})$   

$$\Delta f = \frac{f_{max} - f_{min}}{2} = -l_0^c c \frac{\Delta l}{l_0}$$

$$\rightarrow \frac{\Delta f}{f_0} = \frac{-l_0^c c \frac{\Delta l}{l_0}}{l_0^c} = -c \frac{\Delta l}{l_0}$$

### **Exercise 6:**

In this exercise you will check, that if  $\Delta l \ll l_0$ , then  $\left(1 + \frac{\Delta l}{l_0}\right)^c \approx 1 + c \frac{\Delta l}{l_0}$  and  $\left(1 - \frac{\Delta l}{l_0}\right)^c \approx 1 - c \frac{\Delta l}{l_0}$ . Let  $l_0 = 50$  and  $\Delta l = 1$ .

С	0.5	2	3	-3	-2	-0.5
$\left(1+\frac{\Delta l}{l_0}\right)^c$						
$1 + c \frac{\Delta l}{l_0}$						
Is $\left(1 + \frac{\Delta l}{l_0}\right)^c \approx 1 + c \frac{\Delta l}{l_0}$ ?						
$\left(1-\frac{\Delta l}{l_0}\right)^c$						
$1-c\frac{\Delta l}{l_0}$						
Is $\left(1 - \frac{\Delta l}{l_0}\right)^c \approx 1 - c \frac{\Delta l}{l_0}$ ?						

## Average of repeated measurements

**<u>Rule 5:</u>** The resultant error in the average of measurements of the same quantity repeated *N* times is the error of one measurement divided by the square root of the number of measurements.

$$f = \frac{l_1 + l_2 + \dots + l_N}{N} \quad \rightarrow \quad \Delta f = \frac{\Delta l}{\sqrt{N}}$$

### Example 5:

The following are 9 repeated measurements for l.

91.38, 89.57, 89.57, 89.17, 88.19, 90.52, 88.87, 90.82, 89.84

Find the average of these measurements and estimate the error in the average value.

### Answer 5:

You can use Excel function AVERAGE() to find the average value and Excel function STDEV.S() to find the standard deviation.

Average value =  $\bar{l}_0 = \frac{91.38+89.57+89.57+89.17+88.19}{9} = 0.52+88.87+90.82+89.84}{9} = 89.77$ 

$$\Delta l = \sqrt{\sum_{i=1}^{N} \frac{(l_i - \bar{l})^2}{N - 1}} = \sqrt{\frac{(91.38 - 89.77)^2 + (89.57 - 89.77)^2 + \dots + (89.84 - 89.77)^2}{9 - 1}} = 0.945$$
  
$$\Delta \bar{l} = \frac{\Delta l}{\sqrt{N}} = \frac{0.945}{\sqrt{9}} = 0.315$$
  
$$\bar{l} = \bar{l}_0 \pm \Delta \bar{l} = 89.8 \pm 0.3$$

### **Exercise 7:**

The following are 16 repeated measurements for <i>l</i> .
55.08
55.84
58.63
53.16
59.84
56.55
54.35
54.69
53.95
55.38
52.57
54.39
53.83
56.31
52.84
55.34
Find the average of these measurements and estimate the error in the average value.

### Justification for Rule 5:

There are two types of errors in a measurement: systematic error and random error. The systematic error is a fix and repeatable shift in the measurement caused, for example, by an incorrectly calibrated instrument. The random error varies unpredictably from one measurement to another due to uncontrollable variations in the experiment. For example, the effect of the room temperature on the length of a ruler.

In this lab, we assume that measurements have no systematic errors, and only have random errors. Random errors often have a normal probability distribution, as shown in Fig. 2. The most probable value  $l_0$  is the mean of the distribution and the error  $\Delta l$  is usually taken as the standard deviation of the distribution. There is a chance of 68% for a measurement to be between  $l_0 - \Delta l$  and  $l_0 + \Delta l$ .



Fig. 2. Probability distribution for a random value with a normal distribution.

For adding or subtracting two independent measurements, Rule 1 gives the worst-case scenario. Statistically, it can be shown that a better and smaller estimate of the error is given by

$$\Delta f = \sqrt{\Delta l^2 + \Delta w^2}$$

Thus, for summing N independent measurements of l, a better estimate of the error is

$$\Delta(l_1 + l_2 + \dots + l_N) = \sqrt{\Delta l_1^2 + \Delta l_2^2 + \dots \Delta l_N^2} = \sqrt{N\Delta l^2} = \sqrt{N}\Delta l$$

Hence, the error in the average of these measurements is

$$\Delta f = \frac{\Delta (l_1 + l_2 + \dots + l_N)}{N} = \frac{\sqrt{N\Delta l}}{N} = \frac{\Delta l}{\sqrt{N}}$$

Also, for multiplying or dividing two independent measurements, Rule 3 gives the worst-case scenario. From statistics, a better and smaller estimate of relative error is

$$\frac{\Delta f}{f} = \sqrt{\left(\frac{\Delta l}{l_0}\right)^2 + \left(\frac{\Delta w}{w_0}\right)^2}$$

Rule 2 for multiplying a measurement by a constant and Rule 4 for raising a measurement by a constant hold always since no more than one independent measurement is involved.

In this lab, we will use the worst-case scenario estimate for the error.

### **Exercise 8:**

In this exercise, we will use Excel to check Rule 5. We will use Excel function NORM.INV(RAND(), mean, standard\_dev), which generates a random number with normal distribution. It simulates the process of measurement with a random error. We will generate 30 sets each of which has 25 measurements. For each set, we find its average and its standard deviation. Then we find the average and the standard deviation of the 30 averages. The standard deviation of each set is the error in individual measurement  $\Delta l$  and the standard deviation of the 30 averages is the error in the average value  $\Delta \overline{l}$ . You will check that  $\Delta \overline{l} \approx \Delta l/\sqrt{25}$ .

LO	55.0															
DeltaL	2.0															
number of measurements per set	25															
expected error in the average of a set	0.4															
			set 1	set 2	set 3	set 4	set 5	set 6	set 7	set 8	set 9	set 10	set 11	set 12	set 13	set 14
		measurement 1	52.54	57.10	56.17	57.00	59.13	55.28	53.43	53.41	56.18	54.68	53.19	56.54	56.09	58.57
		measurement 2	55.58	56.53	50.97	56.04	54.56	54.59	55.76	54.31	53.78	55.90	52.53	51.51	55.58	58.50
		measurement 3	53.53	58.14	57.09	54.58	57.53	54.84	54.59	56.50	54.63	54.37	51.78	51.03	53.92	54.36
		measurement 4	53.38	50.66	55.38	56.87	55.19	54.80	53.96	58.17	54.60	52.78	56.92	56.03	56.51	52.15
		measurement 5	55.67	54.98	53.16	55.10	54.13	55.86	55.46	54.67	55.84	50.77	55.79	55.83	54.06	53.61
		measurement 6	52.02	54.73	55.88	55.70	55.50	52.60	52.11	54.62	54.26	59.71	57.11	55.24	55.70	53.84
		measurement 7	56.56	52.96	55.75	55.29	56.55	53.88	57.24	57.08	54.12	52.58	53.75	54.71	57.12	56.70
		measurement 8	56.92	54.13	52.33	53.27	53.55	55.88	53.12	59.28	53.37	55.82	54.37	59.96	55.38	52.68
		measurement 9	50.27	57.27	54.20	56.73	56.38	56.40	51.56	52.11	53.15	56.28	53.18	54.62	51.71	56.79
		measurement 10	55.89	56.22	58.21	55.54	57.26	56.25	55.52	59.61	54.76	54.03	53.60	58.83	55.62	56.09
		measurement 11	58.93	51.94	57.26	52.47	53.77	52.54	55.20	55.91	56.32	52.46	54.45	53.66	58.13	56.61
		measurement 12	57.55	56.52	53.40	56.74	59.77	54.54	55.78	54.33	58.03	59.18	52.96	51.54	55.10	57.00
		measurement 13	55.84	52.14	52.84	54.94	52.83	57.05	53.53	55.12	51.38	57.13	51.66	58.70	55.10	55.55
		measurement 14	59.02	54.74	58.20	59.48	56.45	50.21	53.85	55.46	55.79	54.84	53.15	55.33	55.81	55.20
		measurement 15	54.19	53.17	56.73	54.26	52.83	53.84	54.28	53.67	57.00	58.42	58.86	53.53	54.17	52.98
		measurement 16	54.27	59.20	55.36	57.70	55.98	55.44	53.54	54.67	54.04	54.65	54.93	57.01	55.57	52.88
		measurement 17	52.28	55.66	58.39	57.60	57.74	56.46	55.17	54.85	53.17	54.42	57.45	53.09	53.68	59.83
		measurement 18	53.07	56.46	55.48	53.55	53.63	54.30	54.69	55.91	53.21	50.47	48.99	56.32	52.74	54.93
		measurement 19	55.94	54.79	50.67	56.43	54.38	51.97	54.12	53.35	53.68	56.69	56.34	57.68	55.89	52.96
		measurement 20	56.05	54.12	56.56	51.78	58.20	52.52	51.90	57.07	58.34	55.51	57.56	54.07	51.70	52.14
		measurement 21	52.92	54.23	52.05	53.19	54.60	55.90	55.45	52.99	55.16	53.92	59.12	53.42	54.04	52.42
		measurement 22	55.02	53.57	56.78	52.62	52.54	56.87	56.62	54.19	52.76	53.46	54.81	50.70	54.55	56.18
		measurement 23	51.42	52.22	55.86	55.42	54.76	54.58	58.60	57.08	53.37	51.94	56.64	56.68	58.83	53.48
		measurement 24	50.72	58.26	53.15	51.95	57.95	55.52	53.77	54.89	52.01	56.39	54.70	59.49	52.38	54.78
		measurement 25	54.57	53.94	54.23	57.36	55.69	48.99	56.17	57.71	51.82	56.00	57.61	57.02	58.71	54.25
		Average of a set	54.57	54.95	55.04	55.26	55.64	54.44	54.62	55.48	54.43	54.90	54.86	55.30	55.12	54.98
		std dev of set	2.4	2.2	2.2	2.0	2.0	2.0	1.7	1.9	1.8	2.4	2.5	2.6	1.9	2.2
Average of set averages	55.1															
Average of set standard deviations	2.1															
standard deviation of set averages	0.35															

You can find step-by-step instructions to do this exercise after Exercise 9.

## **Exercise 9:**

A simple pendulum can be used to measure the gravitational acceleration g. If the oscillation angle is very small, then the period of oscillation T is related to the length of the pendulum according to

$$T = 2\pi \sqrt{\frac{L}{g}}$$

For a pendulum of length  $L = 60.0 \pm 0.2$  cm, 10 different measurements of the period in seconds are found to be

1.58

1.57

1.56

1.57

1.53

1.55

1.55

1.55

1.54

1.60

Find the value of gravitational acceleration and estimate its error.



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3	number of measurements per set	25																	-
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31		Average of a set																	_
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#### KFUPM-Phys102-202-Lab-01 02-Feb-2021 日 9、 ® ~ x<sub>2</sub> x<sup>2</sup> ... ~ ⊽ AutoSave (O off) Book1 - Excel Q Search Abdulaziz Aljalal AA Data Developer Help Share Comments File Home Insert Draw Page Layout Formulas Review View S ∑ AutoSum X Cut 98 ≡ = = ≫ - >¶ - cb Wrap Text ~ A A ~ 11 Calibri Number Fill ~ Copy Conditional Format as Cell Sort & Find & Analyze Paste Insert Delete Format BIU~ H~ &~ A~ Merge & Center × \$ - % 9 80 Clear Y S Format Painter Formatting ~ Table ~ Styles Filter v Select Data 15 Alignment I, Styles Clipboard 5 Font Number 5 Cells Editing Analysis Sensitivity =NORM.INV(RAND(),L0,DeltaL) D6 × fx В C D E G н J K L M N 0 P Q R T S LO 55.0 1 2 DeltaL 2.0 3 number of measurements per set 25 4 expected error in the average of a set 0.4 5 set 1 set 2 set 3 set 4 set 5 set 6 set 7 set 8 set 9 set 10 set 11 set 12 set 13 set 14 set 15 set 16 set 17 6 51.21 measurement 1 7 56.44 measurement 2 8 55.97 measurement 3 9 measurement 4 55.83 10 measurement 5 53.85 11 54.94 measurement 6 12 55.47 measurement 7 13 measurement 8 51.21 14 56.72 measurement 9 15 measurement 10 53.37 16 53.76 measurement 11 17 measurement 12 55.42 18 51.84 measurement 13 19 55.39 measurement 14 20 55.11 measurement 15 To copy the formulas of the selected cells to the 21 measurement 16 54.66 22 57.75 measurement 17 cells on the right, move the mouse to the right-23 57.06 measurement 18 bottom corner of cell D30 until the mouse pointer 24 measurement 19 54.22 25 measurement 20 53.49 changes into a cross as shown. Click, hold, and 26 56.07 measurement 21 move the mouse right to cell AG30 then release 27 measurement 22 52.83 28 measurement 23 52.18 the mouse. 29 measurement 24 56.18 30 measurement 25 59.51 31 Average of a set 32 std dev of a set 33 Average of set averages 34 Average of set standard deviations 35 standard deviation of set averages 36 37 error in average (+) 4 ÷. 田 E 巴 Average: 54.82 Count: 25 Sum: 1370.49 Settings 1009

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D31	- × √ fr =a	verage(D6:D30)																	
1	A	ВС	D	E	F	G	н	Ű.	J	к	L	М	N	0	Ρ	Q	R	S	Т
1	LO	55.0																	
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5			set 1	set 2	set 3 s	et 4 s	et5 s	et 6 s	et 7 s	set 8 s	et 9 s	set 10 s	set 11 s	set 12	set 13	set 14	set 15	set 16	set 17
6		measurement 1	54.86	55.10	56.00	54.59	55.92	58.93	56.67	57.24	55.71	54.07	55.03	51.83	57.79	59.32	53.99	55.38	54.
/		measurement 2	55.28	53.92	56.50	57.05	58.43	54.76	54.91	55.87	57.32	53.00	55.23	53.64	53.84	53.07	58.34	54.84	54.
8		measurement 3	55.63	53.04	59.48	56.44	55.84	54.55	55.70	57.45	55.04	57.98	53.46	57.64	54.75	53.63	58.20	51.37	55.
9		measurement 4	53.64	54.40	55.59	55.01	56.07	52.00	53.97	55.42	54.00	51.00	55.71	52.92	54.14	51.74	55.27	10 75	52.
1		measurement 6	55.90	53.00	54.66	57.61	54.20	55.99	51.00	56.05	57.67	54.71	53.71	50.77	50.00	57.92	55.70	49.75	53.
12		measurement 7	57.16	56.46	56.12	55.06	50.06	59 72	52.32	57.15	5/.0/	56 79	57.09	52.72	57 22	57.05	55.70	57.11	54
13		measurement 8	56 59	55.46	19.12	54.54	53.35	54.62	53 17	53.83	56.43	57.90	55 55	57.42	55 20	56 39	55 10	53 30	
14		measurement 9	56.04	54.25	58.87	53.43	56.87	54.52	57.02	57.00	55.99	57.80	53 12	56.82	55 52	52 58	52 73	59.43	2 53
15		measurement 10	56.77	54.53	58.01	55.05	59.14	53.45	56.60	54.55	53.58	55.60	57.49	56.19	53.88	55.33	53.27	60.37	7 56
16		measurement 11	55.01	57.13	54.37	54.99	48.71	56.05	53.39	54.53	53.63	55.60	56.32	56.50	50.69	56.46	57.01	55.20	) 54.
17		measurement 12	57.16	53.31	56.22	57.23	53.99	54.53	57.29	56.17	53.87	55.52	55.63	53.94	56.49	55.25	51.55	53.46	5 55.
8		measurement 13	54.00	53.62	54.10	56.16	56.61	56.39	56.72	53.98	56.05	54.72	51.74	55.87	53.20	55.29	54.84	54.07	57.
19		measurement 14	51.88	54.86	53.63	55.57	52.77	53.18	57.65	53.67	54.02	55.22	58.97	54.67	54.09	54.02	56.13	54.97	54.
0		measurement 15	54.90	57.20	53.10	55.09	52.57	60.55	53.10	54.28	53.73	54.01	52.86	56.29	54.17	55.27	55.70	55.40	56.
1		measurement 16	54.86	54.09	56.69	57.86	54.38	52.38	54.69	53.81	52.68	60.77	54.65	54.27	52.61	53.90	56.05	54.98	53.
2		measurement 17	53.62	57.57	57.10	57.37	52.27	53.94	58.24	52.83	56.63	57.97	53.84	55.57	56.01	53.78	57.62	55.11	57.
3		measurement 18	54.21	56.02	57.29	57.61	50.44	57.06	50.88	53.10	53.04	55.47	56.39	50.09	56.37	58.59	54.58	53.52	55.
4		measurement 19	55.54	55.69	57.25	53.37	56.78	51.38	55.74	54.18	55.04	55.73	52.60	54.74	50.45	52.54	52.18	55.47	54.
25		measurement 20	54.85	56.46	53.38	52.58	56.62	48.62	56.38	55.97	55.87	53.89	58.36	59.26	52.81	54.14	53.69	53.63	53.
26		measurement 21	55.71	58.14	55.55	52.25	53.75	52.27	52.83	55.92	57.04	57.31	53.48	57.18	58.77	55.55	54.20	57.38	\$ 56.0
27		measurement 22	54.38	53.43	53.00	53.46	53.50	53.59	55.95	55.86	54.38	59.20	56.15	54.45	55.47	53.95	52.47	54.46	53.
28		measurement 23	52.22	57.00	57.41	57.03	55.29	54.53	55.33	59.40	51.58	54.53	54.85	50.11	57.52	56.02	54.63	51.84	53.
29		measurement 24	53.02	56.63	55.79	55.30	57.29	55.96	55.12	55.55	54.76	56.00	55.29	53.46	54.65	56.73	54.65	54.64	56.
80		measurement 25	53.86	54.86	54.45	54.62	55.18	55.21	54.86	55.51	56.87	53.74	51.31	59.84	56.04	57.05	49.90	58.54	55.
11		Average of a set	=average(D6:0	030) I	-		100												
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33	Average of set averages							, ,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,											
34	Average of set standard deviations						=aver	rage(L	06:D30	J)									
35	standard deviation of set averages					as sh	nown	then n	resse	enter									
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1	LO	55.0																		
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3	number of measurements per set	25																		
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5				set 1 se	et 2	set 3 set	et 4 s	et 5	set 6	set 7 s	et 8	set 9 s	et 10 :	set 11	set 12	set 13	set 14	set 15	set 16	set 17
6		1	measurement 1	49.93	58.01	53.67	54.72	52.82	54.86	52.42	56.29	57.00	54.91	54.16	52.22	54.77	55.43	53.98	54.96	54.45
7			measurement 2	54.82	55.37	54.85	56.16	54.17	53.29	55.89	54.85	54.93	53.71	55.36	56.19	56.20	54.97	53.61	52.66	55.22
8			measurement 3	52.86	54.03	51.88	54.23	55.55	56.00	55.58	55.07	54.94	55.67	58.68	53.64	55.92	57.09	53.74	54.20	58.44
9			measurement 4	58.41	54.55	57.69	55.85	54.40	55.89	56.89	54.85	53.21	53.89	53.58	56.99	55.64	57.37	54.43	52.43	54.31
10			measurement 5	54.88	58.59	54.30	55.96	55.74	53.78	58.22	52.65	52.29	54.02	54.72	55.00	52.55	55.73	56.79	52.93	52.24
11			measurement 6	51.94	53.61	54.01	55.77	55.19	56.19	54.97	53.31	56.57	56.57	54.04	52.37	54.96	53.51	54.01	55.49	55.11
12			measurement 7	54.97	51.62	56.14	54.25	54.04	58.01	56.99	54.35	56.91	53.43	58.54	53.14	55.06	54.44	56.67	55.34	55.13
13		-	measurement 8	57.53	55.1/	55.75	53.30	54.25	54.14	53.86	54.67	56.72	54.78	56.52	52.54	54.74	57.28	54.53	57.05	56.07
14			measurement 9	52.73	53.31	53.58	55.74	55.01	51.88	54.88	54.30	50.97	57.53	52.60	53.55	51.10	56.12	54.51	54.48	55.92
15			measurement 10	50.74	54.40	57.44	52.02	55.95	57.10	54.04	54.29	52.48	54.47	53.73	55.93	54.50	57.20	51.21	54.57	53.43
17			measurement 11	53.64	18 22	56.17	55 15	50.15	52 72	57.09	51.90	57.57	40.66	52.79	52.06	59.09	59.08	57.51	52 20	54.7/
18			measurement 13	56.82	53 76	53.40	56.72	52.61	55.76	55 72	58 52	52.21	52 /1	52.38	51.64	52.88	54.66	54.63	53.50	55.62
19			measurement 14	58.51	50.70	57.53	48.97	57.38	56.44	56.27	60.33	52.21	53.96	50.25	54.56	53.85	53.68	54.85	52.61	54.48
20			measurement 15	51.40	51.69	53.56	53.86	52.79	59.77	51.11	54 38	56.14	55.93	52.61	52.33	53.28	55.48	55.42	54 37	55.24
21			measurement 16	54.66	57.63	56.23	54.81	53.78	57.19	54.72	57.28	52.95	55.07	55.21	55.51	57.83	54.60	55.81	57.03	53.63
22			measurement 17	57.94	52.32	53.74	55.34	51.96	55.67	59,60	57.33	53.54	54.17	59.58	54,79	58.73	53.68	56.90	54.58	58.82
23			measurement 18	56.40	53.36	52.74	56.45	54.11	55.40	52.78	52.45	57.18	55.79	54.75	54.37	58.36	56.67	55.11	56.10	54.11
24			measurement 19	56.31	56.28	55.38	52.01	58.61	55.68	53.18	55.49	49.93	54.80	56.88	53.35	57.02	52.19	53.96	55.61	57.45
25			measurement 20	54.52	57.40	52.04	52.81	56.61	54.78	55.86	57.73	54.71	54.76	56.21	53.52	57.73	51.80	55.44	56.78	53.28
26			measurement 21	54.84	55.09	49.81	52.16										55.29	59.24	58.09	57.09
27		đ	measurement 22	50.77	54.14	53.66	54.05	To	conv tl	he forr	nula c	of cell [	731to	the c	elle or	n the	54.01	57.20	54.69	53.82
28			measurement 23	57.65	55.20	53.55	55.04		copy u				55110			i uic	56.50	52.47	55.69	54.07
29		1	measurement 24	57.35	54.57	57.41	55.08	righ	וt, mo≀	/e the	mous	e to th	e righ	t-bott	om co	rner	56.36	58.73	53.13	52.51
30		1	measurement 25	56.96	54.31	55.14	53.87	of	nell D3	1 until	the m	nouse	nointe	r cha	naes i	into a	57.25	53.26	57.31	55.43
31		-	Average of a set	55.08	<u> </u>					' unu			, pointe		inges i	nito a				
32			std dev of a set		,			cro	ss as s	shown	. Clic	k, hold	l, and	move	e the r	nouse				
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1 L0	55.0																	
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3 number of measurements per set	25																	
4 expected error in the average of a set	0.4																	
5		set 1 s	et 2	set 3 s	set 4	et 5	set 6	set 7 s	et 8 s	et 9	set 10	set 11	set 12	set 13	set 14 s	et 15 s	et 16	set 17
6	measurement 1	54.08	56.97	54.18	55.14	54.32	54.63	56.96	51.77	55.58	55.37	56.10	57.28	52.57	57.00	54.23	53.85	54.4
7	measurement 2	52.43	53.08	55.66	52.04	54.82	56.18	55.00	57.86	55.65	54.35	58.75	54.52	55.88	54.75	53.49	55.94	52.9
8	measurement 3	57.91	56.22	55.11	54.63	57.70	52.68	54.40	54.64	52.55	50.40	54.93	56.26	53.45	55.50	55.61	56.53	54.8
9	measurement 4	51.98	55.33	54.08	53.36	57.02	51.17	51.60	53.27	56.87	54.04	54.55	56.61	55.20	55.75	56.35	51.67	55.2
0	measurement 5	53.74	55.81	51.75	55.18	55.73	52.68	55.88	55.44	52.44	54.62	58.27	57.75	55.90	56.12	55.71	54.20	63.1
1	measurement 6	53.96	56.19	52.20	57.58	56.63	55.65	57.40	56.53	53.85	53.50	53.36	58.35	53.85	54.77	55.09	53.09	52.4
12	measurement 7	52.52	55.73	53.24	55.09	55.39	54.70	53.41	57.49	57.32	55.81	54.21	55.41	53.54	57.43	55.86	57.88	57.6
13	measurement 8	58.90	55.52	53.70	57.05	52.82	51.85	56.70	55.49	51.49	55.59	57.06	57.40	57.92	51.22	57.63	51.13	57.9
14	measurement 9	52.95	54.43	50.28	52.82	56.53	52.35	57.28	55.61	53.03	54.38	53.36	56.94	56.31	55.86	53.58	55.34	53.7
15	measurement 10	55.07	51.40	53.35	52.47	55.27	53.25	52.39	56.47	54.64	57.73	55.30	57.47	55.85	55.23	54.51	54.29	56.0
16	measurement 11	54.27	56.89	54.00	53.58	54.30	55.91	59.77	57.67	53.39	54.82	55.67	50.96	53.45	52.71	54.87	52.34	53.2
17	measurement 12	53.78	53.40	57.55	55.32	53.60	55.13	54.08	54.10	55.83	54.00	54.33	51.12	56.08	56.15	57.35	54.39	53.9
8	measurement 13	54.36	55.15	53.17	56.47	55.72	53.93	57.40	54.92	53.67	50.46	55.65	53.05	55.66	54.45	56.91	54.48	55.3
9	measurement 14	56.64	57.30	56.53	52.75	55.31	56.98	52.16	53.75	57.73	52.21	52.53	56.73	52.23	54.32	53.45	53.46	54.9
20	measurement 15	54.30	56.75	55.77	56.68	53.79	53.96	53.04	56.22	56.13	55.37	53.90	55.65	56.55	55.97	54.97	53.98	56.1
21	measurement 16	54.04	58.66	52.40	56.03	57.03	55.24	56.50	54.74	52.20	54.24	55.50	56.16	55.10	53.69	54.25	50.45	56.0
2	measurement 17	49.76	52.31	54.62	54.19	58.14	54.52	52.24	53.44	51.94	55.27	54.77	55.74	58.18	53.25	55.23	53.01	53.3
23	measurement 18	54.23	55.17	56.50	53.92	54.45	54.53	55.48	55.85	55.97	59.28	53.90	56.04	56.92	56.13	53.61	56.50	55.9
24	measurement 19	55.74	57.00	54.53	56.89	56.08	51.53	55.96	52.95	55.49	52.02	53.96	56.90	57.16	52.81	56.06	53.11	55.4
25	measurement 20	54.38	52.70	55.87	52.49	54.09	53.64	55.19	55.11	54.46	58.21	58.13	53.45	55.52	56.78	53.07	55.64	57.2
26	measurement 21	54.30	55.25	56.01	56.85	55.66	53.57	55.38	52.22	53.63	52.57	54.94	57.02	53.73	55.74	53.77	50.98	57.0
27	measurement 22	53.59	56.30	58.05	56.07	51.11	54.73	54.05	56.36	56.48	57.35	54.42	56.35	56.63	55.57	56.48	55.40	52.7
28	measurement 23	55.54	54.85	54.38	53.84	56.60	55.71	57.86	55.79	53.96	52.31	59.22	54.31	54.17	59.58	56.24	53.70	58.1
29	measurement 24	54.59	54.86	54.32	56.13	56.62	56.69	55.35	57.30	55.37	51.56	53.48	56.31	51.15	57.91	58.16	54.19	56.3
30	measurement 25	57.00	56.35	57.16	55.90	53.97	54.90	56.16	52.48	54.23	56.13	51.87	52.65	57.59	58.88	52.40	52.89	53.3
31	Average of a set	54.40	55.34	54.58	54.90	55.31	54.24	55.27	55.10	54.56	54.46	55.13	55.62	55.22	55.50	55.16	53.94	55.5
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5				set 1	set 2	set 3 s	et 4 s	set 5 s	set 6	set 7 s	et 8 s	set 9 s	set 10 s	set 11	set 12	set 13	set 14	set 15	set 16	set 17
5			measurement 1	56.95	56.59	56.55	54.38	54.80	50.00	56.07	55.71	54.41	53.02	54.72	54.58	56.68	53.92	1 56.14	57.31	56.52
7			measurement 2	55.71	58.17	54.26	54.53	56.21	49.86	57.03	55.03	56.73	54.08	58.44	55.28	55.20	56.58	\$ 55.18	51.59	58.22
3			measurement 3	55.41	54.93	53.92	57.86	51.72	52.14	55.71	54.66	51.92	55.84	51.87	53.92	54.97	55.24	56.90	56.96	54.40
			measurement 4	51.91	58.42	54.22	57.60	51.68	53.40	57.08	53.72	52.92	53.55	55.14	53.84	54.53	56.45	52.06	52.00	56.31
1			measurement 5	50.55	55.47	50.88	55.79	56.00	57.88	50.18	54.70	53.70	54.20	53.97	53.22	55.30	55.47	50.01	52.83	57.74
1			measurement 6	58.98	50.64	52.14	58.70	55./1	57.78	52.01	55.18	54.11	54.40	50.75	54.24	55.31	33.31	. 55.40	50.42	55.98
2			measurement 9	52.05	57.56	55.22	52.04	55.57	55.00	54.25	55.09	56.26	57.57	55.99	52.00	54.02	49.99	53.37	54.27	59.75
3 A			measurement 8	50.20	57.50	53.80	53.23	50.07	56.52	51.62	52.87	55.04	57.02	54.90	53.00	54.92	57.0	7 59 6/	53.73	55.02
5			measurement 10	57.50	59.41	55.00	55.00	57.05	52 70	54.52	57.19	50.74	56.47	50.57	54.74	54.05	56.6	7 51.6/	52.91	54.07
6			measurement 11	53.22	54 48	54 69	55 35	56.32	51 58	57.01	55 20	51 74	54 12	55 19	57.07	55.08	2 54.46	5 60.02	52.44	53.30
7			measurement 12	54.97	56.55	53.68	51.87	55.41	53.24	51.68	57.47	55 51	57.16	54.73	56.46	57.23	51.4	1 55.74	55.74	53.43
8			measurement 13	53.99	55.80	56.36	53.21	58.02	54.94	56.23	54.70	49.68	54.65	56.18	55.01	56.37	52.92	2 56.04	57.03	58.89
9			measurement 14	51.90	52.12	57.30	53.88	54.77	53.84	52.76	52.00	53.09	54.94	54.60	57.32	52.08	3 54.58	3 56.73	57.72	53.41
D			measurement 15	55.00	58.17	53.05	56.58	53.36	54.52	53.93	52.38	57.59	57.97	52.45	58.81	55.45	54.48	3 54.96	50.95	55.56
1			measurement 16	53.09	55.23	56.05	54.97										53.27	2 56.88	58.34	53.45
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3			measurement 18	56.91	54.29	53.04	58.16		эруш		iula Ol						54.94	54.07	56.34	54.42
4			measurement 19	52.77	58.64	55.64	58.38	right	, move	e the r	nouse	to the	e right-	-botto	m cor	ner	54.65	5 52.74	53.89	54.37
5			measurement 20	53.46	55.40	53.60	52.60	of ce		until t	he ma	nuse n	ointer	char	naes ir	nto a	55.77	1 55.86	57.53	51.10
6			measurement 21	54.45	54.23	54.00	54,20	01 00						onar		no u	54.73	58.94	53.58	55.15
7			measurement 22	54.24	53.99	55.76	53.99	cross	s as s	nown.	Click	, hold	, and r	move	the m	ouse	53.95	56.85	56.18	57.16
8			measurement 23	54.85	60.81	51.39	54.77	riaht	to cel	IAG3	2 then	releas	se the	mou	se.		57.03	53.54	59.59	54.05
9			measurement 24	54.39	55.33	54.39	55.44										59.05	56.20	55.63	59.84
0			measurement 25	58.54	56.94	56.13	58.08	50.50	32.23	34.32	33.07	30.30	33.23	50.04	30.00	52.17	55.48	\$ 58.01	57.18	53.68
1			Average of a set	54.74	55 94	54.70	55.35	55.05	53.98	55.00	55.10	53.64	54.96	55.32	55.79	54.87	54.71	55.63	55.43	55.33
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11		measurement 6	5	6.91	54.87	57.45	56.47	55	the sha	pe of t	the mo	ouse p	ointer	chanc	aes as	show	/n.		55.27	58.04
12		measurement 7	5	3.74	52.39	51.44	55.42	52	Daubla	, aliak t	home				,				59.74	53.55
13		measurement 8	5	4.62	54.93	54.16	58.14	52	Double	CIICK L	nemo	Juse.						1	54.46	58.11
14		measurement 9	5	6.38	53.93	56.13	53.14	59.4	5 55.27	55.70	57.58	20.93	55.90	54.80	52.87	59.10	54.10	54.09	57,40	52.38
15		measurement 10	5	6.07	52.74	57.35	55.80	51.7	7 56.89	52.36	56.49	56.70	58.20	56.42	58.41	53.50	55.38	55.68	62.49	58.68
16		measurement 11	5	9.53	56.96	54.53	55.35	56.6	52 55.13	50.89	51.87	55.25	55.06	55.54	51.59	56.16	55.45	54.63	58.64	56.02
17		measurement 12	5	4.42	51.04	53.57	56.05	53.2	25 55.21	53.57	56.96	54.57	54.24	54.09	56.66	50.53	54.24	54.72	55.53	56.05
18		measurement 13	5.	2.78	56.32	57.40	57.92	55.9	9 52.29	56.42	54.59	51.28	55.86	53.37	59.47	59.03	55.17	55.77	53.22	56.82
19		measurement 14	5	3.09	55.20	53.67	54.86	52.5	55 57.59	53.90	57.87	57.45	53.36	56.95	57.10	57.11	58.01	57.00	53.58	52.44
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21		measurement 16	54	4.84	56.61	55.95	55.41	56.2	21 53.46	54.87	54.33	52.10	56.69	54.30	53.50	54.67	50.97	55.40	54.19	54.64
22		measurement 17	5	5.77	54.46	55.40	57.29	56.3	53.36	54.52	56.05	56.67	54.99	55.88	56.50	53.77	55.86	54.87	54.86	55.92
23		measurement 18	5	0.08	55.03	57.59	54.74	55.1	56.21	55.72	56.58	53.51	54.27	54.45	55.59	52.65	56.95	56.02	54.73	59.05
24		measurement 19	5	2.57	56.01	52.52	59.06	53.3	59.67	57.91	52.20	53.04	50.81	53.15	52.85	55.10	52.38	51.89	56.45	56.33
25		measurement 20	5	3.95	54.30	56.02	55.61	55.9	93 55.11	53.53	51.75	57.94	57.71	55.88	53.69	56.16	53.43	56.82	51.64	56.06
26		measurement 21	5	6.68	56.20	57.62	53.59	53.9	57.43	57.04	55.38	56.25	55.55	55.64	55.96	50.56	57.54	57.26	54.39	54.42
27		measurement 22	5	5.80	58.48	53.54	51.33	54.8	54.32	55.43	55.34	55.50	50.93	54.98	51.76	53.82	53.56	56.64	58.21	56.36
28		measurement 23	5.	3.55	54.87	53.70	54.70	56.4	4 52.76	59.41	56.27	56.77	53.35	53.67	50.84	54.52	56.40	53.49	53.87	57.74
29		measurement 24	5	2.72	55.10	52.23	57.18	52.6	55.66	52.72	53.01	54.55	58.33	53.47	50.19	51.66	53.36	56.13	53.62	59.90
30		measurement 25	5.	3.97	56.70	55.22	52.49	56.5	53.76	59.26	53.24	53.02	54.49	54.96	56.14	54.81	55.28	55.55	57.12	54.9.
31		Average of a set	5	4.32	55.58	55.03	55.36	55.1	14 55.00	54.76	54.66	55.00	54.97	55.26	54.90	54.25	54.79	55.23	55,56	55.55
32	And and the second second second	std dev of a set	-	1.96	1.97	2.01	2.07	2.0	1.99	2.31	1.96	1.90	1.96	1.33	2.51	2.78	1.90	1.92	2.91	2.34
33	Average of set averages																			87
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7			measurement 2	56.05	57.36	56.03	54 70	53 75	53.34	56 18	55 18	56 25	50.05	56 14	58 32	54 20	54.26	53 44	52 43	53.00	55 59	54 52	54.48	54.00	56 31	57.16	54.61	57 29	54 9	2
2			measurement 3	56.34	55 34	56.26	54.85	53.75	56.81	53.46	53.44	52 03	54.45	51 74	56.42	60.28	56 35	56.68	55.85	51.71	56.02	56.08	52 27	54.06	54.64	53 70	55.81	54.02	53.00	5
,			measurement 4	56.22	53 35	55 49	53 67	54 15	54 77	58 57	56 39	50.91	55 54	54.86	54 84	53.93	52 11	57 38	51.89	52.76	53.78	54.87	50.86	52 13	56.90	58.89	53.90	55.44	53.6	7
2			measurement 5	50.68	53.36	54.11	51.97	56.35	55.59	53.03	52.38	57.41	57.26	55.95	58 31	57.25	56.17	51.84	55.52	55.08	53.81	54.01	56.75	53.09	53.26	51.79	53.81	52.99	54.84	4
1			measurement 6	52.55	53.12	55.57	52.93	54.61	56.48	55.05	54.25	56.78	54.13	51.43	54.33	53.21	54.52	56.57	55.33	57.49	51.94	53.38	55.51	54.91	55.24	53.56	56.11	54.70	55.4	7
>			measurement 7	50.26	53.81	58.58	57.62	57.00	51.55	56.61	54.64	54.11	56.46	52.62	55.77	54.32	59.59	49.30	55.81	59.07	52.77	52.83	58.29	58.22	55.09	54.10	55.16	54.60	53.76	5
3			measurement 8	52.19	54.94	53.75	54.60	52.28	56.06	57.10	56.99	55.96	54.73	55.17	56.83	59.51	53.45	55.37	56.81	55.77	51.80	56.76	52.42	54.06	56.54	58.86	57.81	58.51	53.06	5
4			measurement 9	53.39	54.51	58.76	52.42	56.39	56.40	57.25	54.03	54.76	59.30	56.17	52.29	52.75	54.37	56.14	55.38	52.97	55.57	56.85	50.07	57.66	53.85	55.67	51.70	55.09	54.8	1
5			measurement 10	57.86	57.35	53.95	58.11	53.74	52.40	56.08	56.51	53.86	53.03	58.34	56.09	52.39	53.27	54.35	57.54	54.95	53.40	56.43	54.39	53.91	53.75	51.24	58.11	57.21	53.4	7
6			measurement 11	56.87	54.86	54.83	58.48	56.90	54.03	56.65	58.12	55.73	57.76	50.85	52.84	55.07	54.86	53.76	57.49	55.92	55.07	53.62	57.99	54.56	54.64	50.84	57.90	58.10	54.16	6
7			measurement 12	53.28	53.49	57.38	57.46	53.46	52.76	54.69	54.75	56.17	52.96	54.57	55.24	55.99	57.74	53,40	55.17	51.38	56.44	56.20	53.54	56.49	56.14	52.25	55.88	54.62	57.44	4
B			measurement 13	56.68	53.82	53.25	59.20	53.19	55.36	56.55	55.74	54.16	57.53	54.22	55.23	53.41	54.93	53.36	55.57	56.12	54.27	53.63	54.79	55.62	56.62	54.47	56.07	55.00	53.80	5
9			measurement 14	55.88	52.32	56.85	54.58	55.01	53.65	54.34	54.52	52.81	55.95	55.46	54.24	54.23	54.80	52.03	52.11	52.93	55.09	52.15	55.56	55.79	54.69	54.44	55.34	53.70	51.3	3
)			measurement 15	54.56	54.72	54.31	53.98	53.61	54.61	55.39	57.35	55.27	54.19	52.62	54.46	54.51	53,60	54.91	53.31	53.51	56.28	56.56	50.48	54.35	55.97	54.39	51.40	55.51	56.15	5
1			measurement 16	56.13	53.31	55.19	54.59	52.13	54.28	55.43	55.39	54.76	57.81	59.85	56.05	52.35	50.57	56.53	58.12	55.78	53.53	53.62	55.81	53.86	57.78	59.25	55.40	49.70	55.2	7
2			measurement 17	53.96	55.78	54.22	54.76	55.07	54.90	55.59	56.11	57.03	52.30	56.84	59.94	53.72	51.40	56.62	53.06	54.25	54.72	53.13	54.33	54.76	55.23	56.25	55.87	56.54	55.11	L
3			measurement 18	54.20	55.71	57.05	55.85	54.06	56.36	58.83	55.68	51.26	53.81	54.40	53.31	54.96	57.00	54.58	53.72	53.83	58.45	54.85	58.60	55.17	54.69	54.27	53.81	50.96	53.63	3
4			measurement 19	59.32	55.04	55.79	55.48	57.20	51.14	53.87	55.58	55.48	52.58	52.26	57.09	54.73	52.34	54.77	54.04	56.75	56.26	54.18	55.57	56.36	55.95	56.69	55.08	56.34	55.17	2
5			measurement 20	55.71	54.87	52.18	54.09	55.50	53.61	54.08	54.91	56.66	49.52	54.00	52.38	54.67	56.93	55.92	54.00	51.72	55.18	53.42	52.03	58.56	54.82	54.81	53.54	51.93	52.69	9
6			measurement 21	55.95	52.46	56.64	53.19	51.66	55.23	53.82	52.43	54.94	53.29	55.06	55.21	53.75	56.08	52.80	54.60	55.71	52.04	56.58	55.65	57.34	54.87	59.61	50.89	58.30	54.71	I.
7			measurement 22	54.53	57.93	55.02	55.84	54.32	51.05	56.38	57.87	55.51 5	55.74	52.03	53.81	52.40	60.36	52.87	55.60	57.32	57.97	56.39	53.92	57.35	56.60	57.80	56.21	51.94	53.37	7
8			measurement 23	55.68	51.43	56.60	56.72	52.75	55.78	57.66	55.10	53.53	56.09	54.86	55.62	55.76	57.52	54.15	53.29	53.95	55.78	57.81	55.94	57.20	55.02	56.93	55.35	52.82	54.08	3
9			measurement 24	56.13	53.51	54.49	55.95	57.65	54.59	58.16	53.35	57.63	57.35	52.43	55.71	52.06	53.99	54.92	57.11	53.67	56.35	50.90	57.64	60.09	53.92	55.71	56.15	53.35	53.58	3
0			measurement 25	53.50	52.38	53.75	53.36	50.95	53.71	56.63	50.61	56.70	56.17	55.02	55.78	55.77	56.32	54.22	56.22	55.25	53.61	53.63	52.82	54.22	56.40	54.83	55.33	56.86	54.84	4
1			Average of a set	54.90	54.35	55.51	55.14	54.54	54.40	55.93	54.95	55.02	54.99	54.61	55.33	54,60	55.26	54.31	55.07	54.66	54.93	54.73	54.52	55.47	55.29	55.35	55.14	54.95	54.34	4
2	_		std dev of a set	2.12				NO 1		11	6		1	2.29	1.89	2.04	2.50	1.91	1.77	1.93	1.83	1.74	2.39	1.98	1.19	2.46	1.88	2.40	1.29	5
3	Average of set averages =a	verage(	D31:AG31)		In	ce	II B3	33, t	ype	the	forr	nula																		
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6					d	5 51		1, U		0165	3 61	iter.																		
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1	LO	55.0																										
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3	number of measurements per set	25																										4
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5			set 1 s	set 2 set 3	3 set 4	set 5	set 6	set 7	set 8	set 9 s	et 10	set 11	set 12	set 13	set 14	set 15	set 16	set 17	set 18	set 19	set 20	set 21	set 22	set 23	set 24	set 25	set 26	5
6		measurement 1	51.43 5	53.78 58.8	6 58.04	56.50	56.11	55.84	57.44	55.91	57.27	56.14	56.50	54.86	52.71	52.78	53.08	54.81	53.23	59.87	57.24	57.34	56.30	55.68	56.57	56.52	54.10	
1		measurement 2	56.53 5	57.01 53.9	5 54.28	55.04	52.20	54.60	53.85	56.02	54.32	58.56	55.57	52.91	57.62	54.96	54.22	54.96	52.04	54.17	53.76	54.05	51.49	54.12	53.15	49.44	53.98	
8		measurement 3	54.39 5	54.33 58.5	7 40.85	54.81	54.92	57.60	54.91	56.72	51.38	53.27	57.20	53.38	53.30	53.21	58.62	55.74	56.86	56.32	53.54	51.43	54.98	56.94	53.51	56.97	56.03	5
9		measurement 4	54.57 3	55.44 50.5	0 56 07	52.00	54./1	50.78	58.27	53.40	50.90	55.54	55.48	55.40	52.20	50.15	53.43	57.50	55.55	55.49	53.50	52.25	48.28	57.04	55.57	55.84	54.08	
11		measurement 6	53.97	51.04 54.2	2 57 00	56.70	52.09	55.20	56.39	56.11	53.02	52.00	55.02	51.01	54.02	57.09	52.05	59.55	50.09	50.54	52.05	56.90	54.59	57.04	50.92	10.91	52.15	
12		measurement 7	54.91 5	51 50 57 5	A 54 19	55.07	50.04	52 60	54.20	55.95	54.00	56.44	57.19	59 10	55 01	54.70	51.61	52.66	52 72	56 15	56.08	52.62	19 60	50.62	57.46	45.01	55 21	
12		measurement 9	55 12 9	56 12 55 2	9 54 22	52.45	50.34	52.65	51 60	52.22	56.26	55.01	54 61	54.02	57.08	50.76	54.00	52.00	56.08	55.07	54.95	57.16	40.00	59 72	55 27	52.24	52.05	1
14		measurement 9	52 20 0	56 00 53 6	7 51 07	55 11	54 10	54.15	56.61	52.00	55.28	55 56	57 22	52 20	56 43	55 70	50.25	54 21	50.08	58 98	56 72	60.87	50 72	50.75	54 54	54.97	54.76	
15		measurement 10	56 10 5	54 37 55 6	7 56 23	54.87	56 50	57 50	50.01	53 58	53.40	10 04	55.02	56.26	52.60	51 74	50.23	53.00	51.02	57.60	57.00	52.68	54.60	54.85	54.17	55 28	56 40	÷.
16		measurement 11	58 11 9	53 63 54 4	3 56 60	55 58	54 39	54.80	55.16	55 19	54 75	49.45	57.04	54.86	52.00	56 54	55 70	55 53	55.00	56 55	54 84	52.00	56.20	55 47	52 76	56.53	51 71	1
17		measurement 12	53 97 5	58 61 53 2	9 55 86	52 32	57.93	56 44	55 47	58 13	59 74	53 78	55.49	53 53	56 37	54.00	59 53	56.11	50.06	56.87	51 47	58 77	51 72	58.00	53.06	54.07	54 57	,
8		measurement 13	53.62	54.47 52.9	4 59.07	55.57	58.56	54.66	58.11	55.77	54.44	55.24	55.31	57.45	54.43	52.19	55.15	54.06	55.50	55.41	51.20	52.91	56.74	55.03	57.31	54.20	49.67	,
19		measurement 14	54.52 5	54.43 55.7	4 57.12	55.06	55.49	55.82	54.51	56.81	54.38	55.66	59.05	59.30	57.26	57.53	51.42	53.41	55.00	51.13	59.50	58.65	57.06	54.53	51.97	56.62	52.58	
20		measurement 15	56.08	55.60 53.2	5 55.66	54.90	54.49	56.12	54.73	51.99	56.80	52.73	55.18	53.83	57.35	55.77	56.27	55.19	54.44	55.49	58.43	52.04	55.99	54.72	53.62	55.51	58.09	
21		measurement 16	53.18 9	55.19 55.5	0 54.07	52.53	53.70	56.35	52.72	51.62	55.21	58.71	54.05	56.21	53.22	55.89	55.19	55.70	53.43	57.08	56.97	57.17	55.44	55.55	55.74	54.43	53.32	Ì
22		measurement 17	57.34	55.88 58.9	9 57.11	57.41	57.09	53.59	55.86	54.73	53.81	55.29	57.10	56.68	56.98	55.69	54.01	52.32	54.63	56.27	54.35	51.52	53.75	52.41	55.01	53.24	51.98	
23		measurement 18	53.93 5	53.87 55.3	5 56.77	56.80	53.14	54.43	53.85	54.78	54.69	54.46	57.04	55.88	53.40	53.90	56.67	55.14	52.89	56.33	54.37	57.85	52.60	58.20	54.31	53.80	54.51	
24		measurement 19	51.88	57.58 56.1	2 55.92	55.93	55.08	57.67	52.75	53.11	52.40	54.91	53.45	52.45	57.10	52.82	55.35	55.32	56.12	53.10	57.06	58.52	57.34	56.99	52.85	52.99	56.55	
25		measurement 20	57.73	54.01 57.3	8 54.88	56.63	55.36	54.45	57.09	53.14	56.45	56.97	55.75	53.69	56.82	55.31	53.85	55.57	53.24	54.37	57.18	58.99	56.80	57.50	54.45	56.65	57.39	,
26		measurement 21	55.32 5	53.20 55.8	0 54.77	48.66	54.78	54.19	54.86	55.50	53.80	53.09	54.00	56.57	56.03	56.56	55.59	55.84	55.98	52.75	54.64	59.32	56.37	54.65	56.01	55.69	53.56	,
27		measurement 22	57.97 5	54.09 56.8	4 54.07	57.10	52.31	53.72	55.45	52.66	57.81	52.09	51.92	56.97	55.07	53.73	50.12	55.45	56.47	52.89	57.42	54.68	53.91	55.51	54.96	54.34	55.19	6
28		measurement 23	55.58 5	52.99 54.4	4 58.54	53.83	55.63	54.84	54.22	53.71	52.93	52.71	57.05	53.28	53.87	53.82	53.95	56.07	56.03	56.61	56.87	56.66	53.59	53.77	54.24	55.50	53.65	,
29		measurement 24	55.88	52.43 55.3	4 55.09	55.08	51.31	54.63	53.59	53.82	55.86	59.05	58.14	56.05	58.60	55.71	53.64	54.81	51.44	54.51	54.54	50.65	56.28	57.55	54.43	57.66	56.92	
30		measurement 25	55.43	51.90 54.2	5 55.99	53.80	53.48	53.97	53.36	57.16	56.40	56.26	55.33	56.92	56.16	53.66	53.58	58.98	55.76	56.59	53.16	57.32	56.78	55.58	52.51	56.52	56.02	Į.
31		Average of a set	54.97 5	54.68 55.5	3 55.64	54.88	54.46	55.10	55.17	54.56	54.98	54.80	55.47	55.13	55.22	54.64	54.16	55.21	54.29	55.60	55.17	55.55	54.72	55.50	54.76	54.88	54.40	ł
32		std dev of a set	1.86	1.73 1.7	4 2.03	1.98	2.02	1.36	1.90	1.79	1.94	2.46	1.77	1.95	1.97	1.78	2.33	1.52	2.19	1.97	2.18	3.04	2.61	2.15	1.73	2.03	1.95	
33	Average of set averages	54.94			-						_																	
34	Average of set standard deviations =	average(D32:AG32)		In ce	BB	34. tv	vpe	the	form	nula																		
35	standard deviation of set averages							<u>م. ۸</u>	000	1																		
36				-	=ave	rage	e(D)	52:A	632	)																		
37				as s	how	n, th	en r	ores	s en	ter.	_																1.0	4
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5			Contraction of the second design	set 1	set 2	set 3	set 4	set 5	set 6	set 7	set 8	set 9	set 10	set 11	set 12	set 13	set 14	set 15	set 16	set 17	set 18	set 19	set 20	set 21	set 22	set 23	set 24	set 25	set 26	j s
6			measurement 1	55.37	52.80	52.92	53.82	52.73	53.05	57.01	56.11	52.91	53.76	54.49	53.63	54.25	54.02	57.57	55.40	53.36	56.20	59.76	55.47	53.38	52.93	57.63	54.35	55.14	55.80	)
1			measurement 2	56.17	54.87	53.78	52.24	55.25	57.70	51.44	56.22	2 56.11	57.05	52.58	54.32	52.37	58.54	54.65	53.22	57.94	54.33	57.57	53.67	56.30	54.96	52.03	55.00	56.01	52.57	/
8			measurement 3	55.10	54.66	55.50	54.36	54.//	55.1/	57.16	54.04	57.54	53.90	55.//	54.49	51.78	54.14	55.82	54.66	55.82	51.61	53.55	54.06	57.10	52.50	57.03	53.89	54.85	54.79	9
9			measurement 4	52.07	52.41	53.12	52.55	52.87	59.08	54.52	50.75	50.74	55.51	55.19	54.80	56.02	55.05	57.00	51.85	53.09	55.20	52.50	50.55	52.89	54.00	57.55	50.41	57.87	55.20	2
11			measurement 5	54.04	52.65	57.00	57.40	50.35	55.30	56.08	57.25	53.73	55.10	55.59	57.00	50.02	52.78	56.00	50.74	52.54	55.05	57.44	57.20	54.69	57.02	52.25	52.20	55.54	56.04	+
11			measurement 6	54.35	54.54	55.69	55.22	54.50	54.94	50.42	54.70	53.00	55.17	58.93	54.13	52.55	56.04	50.91	57.72	53.17	55.08	51.80	54.88	49.17	54.18	55.20	53.50	59.50	55.31	1
12			measurement 7	55.50	54.41	54.55	52.51	53.75	55.0/	53.94	52.20	53.47	51.15	57.41	50.01	54.12	54.72	50.20	53.00	54.55	54.21	50.08	57.31	52.02	53.03	54.95	54.70	57.47	54.01	4
13			measurement 8	54.04	54.43	55.85	57.50	54.29	57.21	57.01	58.41	54.00	57.11	55.51	57.37	54.04	57.85	50.42	55.49	51.84	54.82	55.55	52.50	54.40	53.43	53.83	54.98	55.03	59.24	+
14			measurement 9	55.13	50.08	55.08	53.84	57.54	50.54	55.50	55.50	50.18	50.45	50.59	54.80	54./1	55.08	54.95	55.98	60.39	58.71	57.23	55.01	55.29	51.59	55.09	59.39	54.10	50.40	2
15			measurement 10	50.95	5 52.50	55.00	52.90	54.72	57.42	55.22	52.94	50.54	53.04	59.24	53.14	50.90	55.79	53.40	50.99	55.05	50.52	50.15	55.04	53.05	54.50	54.15	55.19	57.12	54.90	2
10			measurement 11	55.50	59.20	55.05	50.12	55.29	55.02	54.05	54.15	55.42	52.45	52.55	55.19	51.08	56.12	50.10	52.04	55.19	55.19	54.07	52.25	55.00	53.14	55.09	54.10	50.70	57.04	*
10			measurement 12	50.27	50.00	55.95	50.49	54.75	55.95	55.71	57.54	55.40	54.57	55.10	57.02	54.71	55.10	59.10	50.92	51.25	54.54	50.00	52.99	53.51	52.74	50.29	55.11	54.09	50.74	-
10			measurement 13	56.76	53.64	56.79	55.45	57 60	54.07	57.20	55.00	53.13	52.93	54.07	55.52	55.74	55 47	57.03	54.11	52.00	50 07	54.91	57.25	57.02	57.50	57.00	53.01	55.07	50.00	2
20			measurement 15	55 39	56 67	53.03	55 56	54 10	53.54	53.00	53.86	52.50	52.75	54.24	55.03	58.46	57.07	58 79	53 52	53.66	55 79	58 55	55.28	53.89	55 58	55.98	51 70	54.17	54.5	2
20			measurement 16	52.99	52.26	55 51	55.15	56.76	51.97	57.26	56 51	55 /1	10 05	55 77	54.96	52.76	52 28	57.16	54.72	55.00	50.29	52.20	57.46	52 72	52.08	55 40	57.65	56.80	51.0	0
27			measurement 17	54.72	56.25	56.72	54.70	52.92	55.94	59.30	57.60	54.05	52 55	56.00	57.97	55.65	54.74	57.10	56.01	54.61	55.56	54.95	5/ 51	57.90	54.25	57.40	57.05	54.00	59.0	2
22			measurement 19	55.91	55.00	54 72	57.00	50.54	55.46	57 72	56.90	55.61	56 47	57 /19	50.46	54.02	56 71	52.70	61.90	56.65	57.24	50 72	52.60	59.01	52 /5	55 20	52.30	52.76	54.1	0
23			measurement 10	56.57	52.00	56 72	56.21	57.69	54.41	57.75	54.94	59 20	57.96	55.00	55 61	51 61	52 50	52 71	56 74	52.03	55 21	54.09	54.00	51.72	56.01	52.14	10.05	52.70	52 5	7
25			measurement 20	53.60	53.05	54.38	56 38	54.46	53 50	54.76	57.49	55.80	57.02	55.14	56.63	54 21	57.64	56.40	58 50	55 18	53.60	52 55	56.00	55 14	55.46	52.65	56 31	54 61	55 5	8
26			measurement 20	56.05	55.00	52 22	55 20	53 61	55.43	52 56	58 40	57 71	54 34	55.80	55 54	55.83	56 14	54.85	51.82	55 76	56 31	55 24	56.63	53.02	59.21	54.80	57.66	55.79	53.1	7
27			measurement 22	54.25	58.47	57.90	51 47	57.28	54.86	55 99	56.40	54 47	54.68	56 79	53.87	54.45	53 64	50 53	56.61	57 33	54 13	53 67	51 35	52 32	55.06	57 79	56.49	54.61	53.9	2
28			measurement 22	56 41	54 41	56.29	55 67	54 40	55 15	57 48	54 75	55 42	57.45	53 74	56.07	51.85	56.22	51 77	53.94	55 50	55 38	51.32	53.46	52.52	53.80	56.80	53 39	59 21	56.50	6
29			measurement 24	57.40	57.26	53.82	55.45	59 11	59.71	54 35	58 11	56.44	54 50	53 36	54.12	53.08	56.62	55.03	55.22	57.86	57.49	53.29	56.56	56 50	55.25	53.50	54.59	55.46	52.76	6
30			measurement 25	56.89	55.21	56.19	53.00	56.50	57.29	55.13	55.06	54.01	52.99	54.85	53.47	55.28	56.43	53.86	55.56	56.29	55.54	55.69	57.00	52.13	57.07	54.29	55.87	55.36	51.5	2
31			Average of a set	55 31	54.71	55.02	55.03	55.01	55 62	55.76	55.50	55.26	54.42	55.28	55.50	54.63	55.81	55.14	55.35	54.84	55.47	55 41	54.82	54.21	54.88	55.06	54.54	55.58	54.9	8
32			std dev of a set	1.32	1.76	1.61	1.90	1.99	1.79	1.92	1.97	1.54	2.05	1.61	1.76	2 26	1.94	2.38	2 43	2.13	1.85	2.45	1.85	2.13	1.94	1.81	2.08	1.74	2.30	0
33	Average of set averages	55.07	,	1.54	. 1.70	1.01	1.50	1.00	1.75	1.72	2.57	2.04	2.05	1.01	1.70	2.20	1.04	2.00	2.45	2.25	1.00	2.45	1.00	2.25	1.04	1.01	2.00	104	2.50	
34	Average of set standard deviations	1 93			In	cell	<b>B</b> 3	5 tv	/pe	the	forr	nula																		
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4	A	В	с	D	E	F	G	н	1	J	к	L	м	N	0	Ρ	Q	R	s	т	U	v	w	x	Y	z	AA	AB	AC -
1	LO	55.0																											
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5				set 1	set 2	set 3	set 4	set 5	set 6	set 7	set 8	set 9	set 10	set 11	set 12	set 13	set 14	set 15	set 16	set 17	set 18	set 19	set 20	set 21	set 22	set 23	set 24	set 25 s	set 2
6			measurement 1	57.05	5 51.06	53.28	55.22	55.49	55.99	60.27	55.77	53.04	1 55.55	55.21	54.40	51.52	51.69	57.85	55.57	58.14	54.03	54.04	54.81	52.51	55.84	52.18	56.28	56.21	54.
7		1	measurement 2	54.18	3 53.52	52.55	51.81	54.86	55.27	56.46	53.33	55.84	\$ 56.29	56.20	58.14	53.88	54.49	55.37	56.24	57.54	60.26	53.22	54.71	54.91	51.75	53.34	54.71	54.82	55.
8			measurement 3	55.28	3 55.50	52.01	54.95	56.77	57.01	55.36	55.04	57.86	5 52.55	55.51	57.38	55.15	58.79	56.06	54.10	53.78	54.35	51.60	57.98	53.53	57.16	53.86	50.49	58.86	55.
9			measurement 4	56.90	55.81	56.59	54.65	55.83	54.10	57.72	52.69	55.98	56.28	58.18	55.48	52.32	57.59	54.19	51.74	54.37	55.35	54.44	54.01	56.62	53.54	56.02	54.12	52.16	55.
10			measurement 5	57.51	54.00	53.94	56.10	54.91	55.99	52.12	57.40	54.00	53.35	55.44	52.62	56.93	52.71	56.79	55.07	52.87	53.89	54.43	53.91	54.04	52.25	55.54	53.38	54.65	50.
11		1	measurement 6	55.08	3 56.25	53.94	55.08	53.10	52.85	52.86	51.28	\$6.70	58.36	56.23	54.46	52.52	55.42	51.54	53.30	53.83	55.53	57.59	56.56	55.03	55.79	57.41	51.85	52.03	55.
12			measurement 7	53.53	57.61	51.09	53.43	53.50	57.47	56.40	51.91	54.45	5 54.15	57.34	56.81	53.73	55.10	57.18	55.91	55.25	54.28	53.91	54.98	53.41	57.21	54.87	54.10	54.41	49.
13		1	measurement 8	56.18	3 55.62	60.82	54.94	51.15	56.13	49.97	56.09	55.30	56.51	55.04	52.73	51.63	55.81	57.75	55.84	53.59	56.18	55.32	56.46	54.87	54.08	55.92	50.27	56.03	57.
14			measurement 9	55.52	2 55.40	51.95	55.62	51.75	54.70	56.70	57.66	51.90	56.06	58.48	57.05	58.15	56.89	56.83	55.09	56.79	58.01	56.59	56.50	53.59	53.43	53.13	53.54	55.15	53.
15		1	measurement 10	54.90	53.02	55.87	54.34	56.79	58.99	51.22	54.31	54.60	55.97	56.51	54.99	54.42	54.49	53.48	55.81	53.91	55.30	55.69	53.57	57.20	54.02	53.81	55.24	57.65	53.
16			measurement 11	54.74	56.91	54.62	57.43	53.13	53.13	56.90	55.71	56.80	51.82	55.34	55.93	51.23	55.00	57.59	57.24	55.73	57.08	57.53	53.64	55.37	55.27	53.83	55.89	55.44	54.
17			measurement 12	54.32	55.95	54.07	52.83	54.98	53.30	57.90	58.61	52.61	55.94	53.76	52.86	52.51	53.80	57.35	52.64	54.74	55.73	56.26	55.11	52.06	54.50	55.96	57.20	54.43	57.
18			measurement 13	52.94	57.62	53.33	55.05	54.30	56.86	56.22	53.97	55.64	1 58.84	56.41	56.43	56.07	54.76	54.67	59.68	54.28	54.37	52.81	57.95	57.23	58.40	57.26	54.94	53.67	53.
19			measurement 14	56.35	5 53.93	54.19	52.19	54.78	55.50	54.20	57.75	56.44	\$ 57.51	52.72	55.61	53.04	52.42	55.86	55.34	51.83	53.30	54.00	54.59	57.73	57.76	52.15	54.02	53.79	52.
20		1	measurement 15	50.99	53.46	57.70	55.92	54.49	54.16	52.78	53 20	53.33	3 54.15	56.07	57.45	55.18	55.25	54.82	56.33	54.53	52.14	50.25	50.36	55.12	54.84	56.37	52.58	50.20	52.
21		1	measurement 16	53.06	5 53.41	50.78	55.58	54.77	57.07	52.91	57.46	52.00	55.69	53.37	52.40	56.44	52.08	55.92	56.27	53.61	54.82	55.64	54.07	56.57	54.97	53.15	53.74	54.23	53.
22			measurement 17	52.55	57.07	54.14	53.75	56.75	54.81	55.75	54.18	54.70	54.58	54.82	54.73	58.05	52.34	57.84	55.84	58.81	52.50	56.85	55.02	54.23	57.36	49.36	55.20	56.30	54.
23			measurement 18	52.83	8 55.49	55.17	52.85	55.51	55.91	54.85	50.93	52.95	5 56.37	52.19	55.30	58.49	54.27	54.41	53.66	53.78	58.27	57.20	55.85	55.60	55.52	52.35	54.14	58.28	55.
24			measurement 19	56.26	5 54.77	55.69	55.25	55.72	55.79	55.44	51.36	54.35	5 55.26	54.07	55.19	53.08	56.12	56.59	54.84	51.70	57.59	57.09	54.50	54.91	57.84	54.93	54.37	57.87	52.
25			measurement 20	54.96	5 53.46	55.29	55.56	53.93	55.92	50.32	56.60	57.17	55.05	55.25	55.85	52.82	57.45	54.10	53.76	55.72	56.23	56.81	55.13	54.92	55.01	56.52	55.89	52.07	56.
26			measurement 21	54.97	56.61	55.14	56.86	55.64	53.79	59.52	54.72	54.12	2 58.01	56.03	55.56	54.58	50.85	58.10	57.49	55.61	55.00	54.68	55.87	55.27	52.97	53.81	51.75	61.14	57.
27			measurement 22	53.39	55.51	58.25	53.76	55.60	56.87	50.47	59.28	58.20	55.79	52.35	56.45	57.56	5 55.41	57.14	55.14	57.55	54.89	53.98	57.24	53.44	59.03	52.65	54.61	52.60	57.
28			measurement 23	55.71	57.20	54.92	56.01	56.31	56.07	54.03	55.26	56.35	5 55.22	56.90	55.86	57.80	53.63	57.41	55.39	54.90	58.23	51.67	53.16	55.93	57.31	56.63	52.81	54.09	55.
29			measurement 24	55.07	56.93	57.41	55.73	55.70	57.25	53.3	57.26	54.75	5 54.41	61.16	51.52	57.79	55.11	53.46	53.40	55.87	51.12	52.19	54.26	58.34	55.00	55.65	53.20	53.34	57.
30		i iiiiiiiiiiiiiiiiiiiiiiiiiiiiiiiiiiii	meas																55.36	53.50	50.23	53.72	55.34	54.79	56.77	55.16	56.31	53.75	53.
31			Avera Color	+ ~~			hon			مالم	ماراس				Г	امدا			55.24	54.89	55.15	54.70	55.02	55.09	55.51	54.47	54.03	54.93	54.
32			std de Selec	CE CE		ວວ, ເ	nen	rep	bea		sking	j or	De	crea	seL	Jeci	mai		1.66	1.84	2.34	2.04	1.63	1.59	1.95	1.94	1.75	2.48	2.
33	Average of set averages	54.99	box t	o sh	now t	wo	dec	ima	al pla	ace	s for	the	e nui	nber	in c	cell	B35.												-
34	Average of set standard deviations	1.89																											
35	standard deviation of set averages	0.38531704			1																								-
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B35	• . > . fx =STD	EV.S(D31:AG31)																								•
1	Α	ВС	D	E	F G	н	I J	К	L	М	N	0	Ρ	Q	R	S	T	U	V	W	х	Y	Z	AA	AB	AC 🛎
1	LO	55.0																								
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3	number of measurements per set	25																								
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5			set	1 set 2 set	et 3 set 4	set 5	set 6 set	7 set 8	set 9 se	et 10 s	set 11 s	et 12 s	set 13	set 14 :	set 15	set 16 s	set 17 :	set 18	set 19	set 20	set 21	set 22	set 23	set 24	set 25 s	set .
6		measurem	nent 1 57.	05 51.06 5	3.28 55.22	55.49	55.99 60	2/ 55.//	53.04 5	5.55	55.21	54.40	51.52	51.69	57.85	55.57	58.14	54.03	54.04	54.81	52.51	55.84	52.18	56.28	56.21	54.
1		measurem	nent 2 54.	18 53.52 5	2.55 51.81	54.86	55.27 56.4	46 53.33	55.84 5	6.29	56.20	58.14	53.88	54.49	55.37	56.24	57.54	60.26	53.22	54.71	54.91	51.75	53.34	54.71	54.82	55.
8		measurem	nent 3 55.	28 55.50 5	2.01 54.95	56.77	57.01 55.	36 55.04	57.86 5	2.55	55.51	57.38	55.15	58.79	56.06	54.10	53.78	54.35	51.60	57.98	53.53	57.16	53.86	50.49	58.86	55.
9		measurem	ient 4 50.	51 54 00 5	2 04 56 10	51.01	54.10 57.	12 52.09	55,98 5	2 25	56.18	53.48	52.52	57.59	54.19	51.74	54.57	55.55	54.44	54.01	50.02	53.54	55.02	54.12	52.10	55.
11		measuren	ient 5 57.	00 56 25 5	2 04 55 09	52.10	53.99 52.	12 57.40	56.70 5	0.26	56.22	54.02	50.95	52.71	51.79	53.07	52.07	55.69	57.50	55.91	54.04	55.70	57.11	55.50	52.02	50.
12		measurem	ent 7 53	53 57 61 5	1 00 53 43	53.50	57 47 56	10 51 01	54.45 5	4 15	57 34	56.81	52.52	55 10	57.18	55.01	55 25	54.28	53 01	54.98	53.05	57.21	54.87	54.10	54 41	10
12		measurem	ent 9 56	18 55 62 6	0 82 54 94	51 15	56 12 /0	7 56 00	55 20 5	6 51	55 04	52 72	51 62	55.91	57 75	55.91	52 50	56 19	55 22	56.46	54.97	54.09	55 07	50.27	56.02	57
14		measurem	ento 55	52 55 40 5	1 05 55 67	51 75	54 70 56	70 57 66	51 00 5	6.06	59 / 9	57.05	58 15	56.80	56.83	55.09	56 70	58.01	56 50	56 50	52 50	52 42	52 12	52.54	55 15	52
14		measurem	ent 10 54	90 53 07 5	5 87 54 34	56 70	58 00 51	70 57.00	54.60 5	5 97	56 51	5/.05	54.42	54.49	53 / 8	55.81	53 01	55 30	55 60	53 57	57.20	54.02	53.15	55.24	57.65	53
16		measurem	ent 11 54	74 56 91 5	4 62 57 43	53 13	53 13 56	0 55 71	56.80 5	1.82	55 34	55.93	51 22	55.00	57 59	57.24	55.73	57.08	57.53	53.64	55 37	55 27	53.83	55.89	55.44	54
17		measurem	ant 12 54	32 55 95 5	4.02 57.43	54 98	53 30 57 9	0 58 61	52 61 5	5 94	53 76	52.86	52 51	53.80	57.35	57.64	54 74	55 73	56.26	55 11	52.06	54 50	55.06	57.20	54 43	57
18		measurem	ent 13 52	94 57 62 5	3 33 55 05	54 30	56 86 56	22 53 97	55 64 5	8 84	56 41	56.43	56.07	54.76	54 67	59 68	54.78	54 37	52.81	57.95	57.23	58 40	57.26	54 94	53 67	53
19		measurem	nent 14 56.	35 53.93 5	4.19 52.19	54.78	55.50 54.3	20 57.75	56.44 5	7.51	52.72	55.61	53.04	57.47	55.86	55.34	51.83	53.30	54.00	54.59	57.73	57.76	52.15	54.02	53.79	52.
20		measurem	nent 15 50.	99 53.46 5	7.70 55.92	54.49	54.16 52.	78 53.20	53.33 5	4.15	56.07	57.45	55.18	55.25	54.82	56.33	54.53	52.14	50.25	50.36	55.12	54.84	56.37	52.58	50.20	52.
21		measurem	nent 16 53.	06 53.41 5	0.78 55.58	54.77	57.07 52.9	91 57.46	52.00 5	5.69	53.37	52.40	56.44	52.08	55.92	56.27	53.61	54.82	55.64	54.07	56.57	54.97	53.15	53.74	54.23	53.
22		measurem	nent 17 52.	55 57.07 5	4.14 53.75	56.75	54.81 55.	75 54.18	54.70 5	4.58	54.82	54.73	58.05	52.34	57.84	55.84	58.81	52.50	56.85	55.02	54.23	57.36	49.36	55.20	56.30	54.
23		measurem	nent 18 52.	83 55.49 5	5.17 52.85	55.51	55.91 54.	85 50.93	52.95 5	6.37	52.19	55.30	58.49	54.27	54.41	53.66	53.78	58.27	57.20	55.85	55.60	55.52	52.35	54.14	58.28	55.
24		measurem	nent 19 56.	26 54.77 5	5.69 55.25	55.72	55.79 55.4	44 51.36	54.35 5	5.26	54.07	55.19	53.08	56.12	56.59	54.84	51.70	57.59	57.09	54.50	54.91	57.84	54.93	54.37	57.87	52.
25		measurem	nent 20 54.	96 53.46 5	5.29 55.56	53.93	55.92 50.3	32 56.60	57.17 5	5.05	55.25	55.85	52.82	57.45	54.10	53.76	55.72	56.23	56.81	55.13	54.92	55.01	56.52	55.89	52.07	56.
26		measurem	nent 21 54.	97 56.61 5	5.14 56.86	55.64	53.79 59.	52 54.72	54.12 5	8.01	56.03	55.56	54.58	50.85	58.10	57.49	55.61	55.00	54.68	55.87	55.27	52.97	53.81	51.75	61.14	57.
27		measurem	nent 22 53.	39 55.51 5	8.25 53.76	55.60	56.87 50.4	47 59.28	58.20 5	5.79	52.35	56.45	57.56	55.41	57.14	55.14	57.55	54.89	53.98	57.24	53.44	59.03	52.65	54.61	52.60	57.
28		measurem	nent 23 55.	71 57.20 5	4.92 56.01	56.31	56.07 54.0	3 55.26	56.35 5	5.22	56.90	55.86	57.80	53.63	57.41	55.39	54.90	58.23	51.67	53.16	55.93	57.31	56.63	52.81	54.09	55.
29		measurem	nent 24 55.	07 56.93 5	7.41 55.73	55.70	57.25 53.3	31 57.26	54.75 5	4.41	61.16	51.52	57.79	55.11	53.46	53.40	55.87	51.12	52.19	54.26	58.34	55.00	55.65	53.20	53.34	57.
30		measurem	nent 2 To	- chan	an the	font	color	of		5 to	rod			57.58	52.43	55.36	53.50	50.23	53.72	55.34	54.79	56.77	55.16	56.31	53.75	53.
31		Average of	fa set	Julan	ye me	ion	COIOI			5 10	reu	,		54.76	55.79	55.24	54.89	55.15	54.70	55.02	55.09	55.51	54.47	54.03	54.93	54.
32		std dev of	a set Se	elect c	ell B35	5 the	n clicł	c on t	he ar	row	/ to s	sele	ct	2.02	1.85	1.66	1.84	2.34	2.04	1.63	1.59	1.95	1.94	1.75	2.48	2.
33	Average of set averages	54.99	ro	d colo	r from	stan	dard	color	c																	
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1	LO	55.0																										
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5	1		measurement 1	Set 1 5	Set 2 9	Set 3 Set 4	+ set 5	Set 6	set /	set 8	set 9	Set 10	Set 11	Set 12	Set 13	Set 14	Set 15	SET 16	SET 17	Set 18	Set 19	Set 20	Set 21	Set 22	Set 23	Set 24	Set 25 s	60
7		/	measurement 2	57.24	56.38	48.85 52.	48 54.5	2 51.52	54.45	54.59	55.76	57.14	52.25	53.56	55.36	56.11	55.24	58.09	52.98	52.89	52.67	56.78	58.05	55.21	53.31	56.00	57.22	55.
8	1		measurement 3	51.90	51.62	54.15 54.	86 56.4	5 54.90	54.81	56.17	56.21	58.18	57.01	55.94	54.17	53.94	51.62	52.64	55.66	55.30	52.64	60.43	49.70	52.57	55.39	53.41	57.72	55.
9		1	measurement 4	51.22	55.44	56.93 58.7	12 54.94	4 53.67	54.78	3 55.76	57.75	54.56	53.54	55.71	56.20	52.63	53.00	57.65	54.06	56.65	52.36	55.49	58.17	55.10	56.69	51.87	57.71	55.
10			measurement 5	56.27	54.09	54.13 55.4	43 54.99	56.37	57.45	54.78	54.80	53.94	53.20	52.57	51.63	55.95	57.24	57.07	55.20	54.51	58.04	56.17	55.15	55.25	57.50	57.20	51.39	56.
11	· · · · · · · · · · · · · · · · · · ·		measurement 6	55.07	52.61	56.65 55.8	33 54.83	\$ 55.73	56.26	49.78	53.87	54.03	55.17	55.92	58.94	55.19	51.16	53.50	57.70	52.70	54.63	55.47	52.28	54.63	52.67	56.49	54.09	53.
12	4	/	measurement 7	57.12	53.91	56.14 54.4	15 53.59	57.75	53.12	. 52.96	55.88	59.96	53.76	53.09	59.10	58.17	53.00	53.82	54.46	55.62	53.17	55.36	54.34	55.32	57.92	56.78	56.52	53.
13		Y	measurement 8	52.06	54.99													54.21	57.71	57.28	53.63	58.15	56.07	55.44	57.49	51.43	53.66	54.
14		/	measurement 9	55.45 :	52.03	_												6 20	52.77	58.15	51.05	55.54	54.64	58.01	57.22	54.96	55.02	52.
16			measurement 11	58.62	55.83	Pres	,s ⊦9	to u	lbde	ate tr	ne r	and	om r	านท	bers	3. IT		7.29	54.57	55.07	56.52	54.00	54.19	55.23	56.05	54.43	49.78	58
17	1		measurement 12	56.47	55.43	vou '	ores <sup>,</sup>	s F9		uple	oft	time	s. vo	u ca	an ne	otice	ć	5.06	54.52	52.08	56.96	56.60	54.83	53.34	54.83	52.25	56.41	53.
18	( /		measurement 13	54.14	52.94	that	tho	ton	dore	4 40	viati	ion c	fac	+ 01/	arad		ī	8.57	58.03	57.74	54.95	54.82	51.62	56.10	56.26	55.00	57.40	55.
19		1	measurement 14	60.05	54.57	that	me s	land	Jaro	luev	Лаш	0110	Isei	lave	erag	es 🏼	1	6.23	53.41	58.78	55.22	58.36	51.15	53.74	54.86	54.62	51.69	54.
20			measurement 15	55.16	52.58	varie	s ar	ound	10.4	4. If	you	u us	e mu	ich r	nore	e set	ts,	3.73	54.85	56.20	54.84	54.31	52.34	57.29	54.10	53.07	55.95	55.
21		J	measurement 16	54.51	54.99	its v:	ariati	on h	heco	mer	ssr	nalle	r					55.96	54.52	52.91	51.16	56.87	58.37	58.03	52.17	56.08	57.75	54.
22	4	/	measurement 17	54.08	56.48		man		000	moe	5 511	land	1.					53.98	53.82	52.99	54.29	57.86	59.50	51.53	56.91	55.26	51.19	48.
23	A	/	measurement 18	53.22 *	54.63													54.70	56.70	57.55	53.74	57.18	55.63	54.64	53.31	56.64	51.90	52.
24	( )	/	measurement 19	56.30	55.53	50 47 EE	1 55.20		51.01	2 55 61	55.12	54.06	56.20	55.04	55.05	50.02	51.55	53.35	54.04	53.98	60.56	54.06	55.25	55.55	55.43	55.22	53.15	56.
25		/	measurement 20	54.66	55.08	58.47 55.2	9 52.70	1 55.45	56.97	50.01	54.72	54.00	54.40	56.34	55.81	50.03	55.27	57.10	59.42	53.73	55.50	55 71	53.90	54.41	51.59	59.00	55.22	54.
27	(		measurement 22	53.34	58.67	57.50 51.	21 57.1	0 52.36	52.95	53.50	53.14	1 55.29	54.97	58.27	51.06	50.38	54.43	57.24	54,53	52.44	53.02	55.83	57.68	56.39	55.40	51.16	56.24	56.
28	1		measurement 23	51.21	56.69	53.97 56.	91 53.34	4 51.10	51.38	3 53.83	52.43	53.76	58.07	53.10	54.59	55.82	56.64	56.05	56.69	55.44	56.59	53.22	54.14	52.15	56.79	57.37	56.03	54.
29		1	measurement 24	55.11	56.06	52.85 50.0	35 55.26	5 56.84	53.68	3 56.93	52.27	54.67	56.28	54.74	52.82	53.27	56.54	55.06	54.79	54.55	55.36	54.46	55.94	50.84	55.09	59.76	57.53	55.
30		1	measurement 25	54.53	54.33	52.18 55.1	15 54.28	3 53.64	56.34	\$5.88	53.94	56.21	51.56	53.46	54.58	55.79	54.08	55.60	56.49	53.22	57.19	55.29	55.74	55.55	58.10	58.40	56.09	53.
31		1	Average of a set	54.55	54.71	54.94 54.5	54 55.25	5 54.61	. 54.81	55.11	55.16	54.75	54.63	55.40	54.57	55.24	54.60	55.43	55.14	54.95	55.07	56.25	54.76	54.76	55.41	55.35	55.06	54.
32			std dev of a set	2.33	1.61	2.30 2.1	18 2.27	/ 1.85	1.72	2.50	2.59	2.06	1.87	2.05	1.97	2.47	1.94	1.72	1.62	2.07	2.30	1.93	2.49	2.10	1.79	2.36	2.36	2.
33	Average of set averages	55.00	0																									
34	Average of set standard deviations	2.11																										
35	standard deviation of set averages	0.42																										
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