Investigating Types of Errors*

Question: Why should repeated measurements of a single quantity give different values?

Answer: Because with any measurement two types of errors will muck the results.

1. A **Systematic error** results from an uncalibrated device, or a measuring technique which **always** makes the measured value either larger or smaller than the "true" value, for example, using a steel ruler at liquid nitrogen temperatures to measure the length of a rod. At low temperatures the ruler will contract, and you will overestimate the true length. Careful experimental design will eliminate or to correct for systematic errors.

2. **Random errors,** present even when all systematic errors are eliminated, occur in a measured value due to the irreproducibility in making replicate measurements. These errors result from biases introduced by instrumental method, or human factors. Deviations due to **random errors** can be dealt with statistics.

This activity will explore the effects of random and systematic errors.

A scientist weighed a set of standard masses in grams on four different balances. Assume each standard mass is the true value with no error.

Standards	Balance 1	Balance 2	Balance 3	Balance 4
2.00 g	2.00	4.00	1.70	1.81
5.00 g	5.00	7.00	4.25	5.57
10.00 g	10.00	12.00	8.50	9.57
15.00 g	15.00	17.00	12.75	15.67
20.00 g	20.00	22.00	17.00	20.89
25.00 g	25.00	27.00	21.25	24.12

*This activity was designed by Scott Sinex and modified for this lesson. Go to this site at http://academic.pgcc.edu/~ssinex/errors_act.pdf for the updated version.

Name _____ Period ____ Date _____

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Examine the chart and answer the following questions.

1. Describe the differences among the measurements taken with each of the four different balances?

2. Why do think the measurements are different?

3. Using Excel, plot the standard mass on the x-axis and the balance mass on the y-axis for each balance separately.

4. Perform a linear regression from the graph for each balance.
   (right click on the graph → add trend line → type: linear → options: display equation on chart, display R-squared value on chart)

5. In the first two rows of the Table below, describe the discrepancies, patterns or trends between the true values and the measured values for each balance.

	Balance 1	**Balance 2**	**Balance 3**	**Balance 4**
Description of error				
Type of error (random or systematic)				
Description of graph				
Linear regression equation				
Value of R^2				

6. Does the linear regression equation (linear fit) describe the measurements taken with each balance? Remember that the x-value is the standard mass and the y-value is the measured mass).

   - Balance 1:
   - Balance 2:
   - Balance 3:
   - Balance 4:

7. The linear equation is not good at describing the error(s) of measurements taken with balance 4. Why?

8. The correlation coefficient, R^2, is a gauge of the quality of the fit. A perfect fit has $R^2 = 1$, meaning that the measurements have no error (rarely found with real data). Good fits of experimental data typically have R^2 greater than 0.9. If R^2 is less than 0.9; the model used to describe the data is probably not a good. Use the R^2 values to determine whether a linear fit is a good for systematic or random errors. If not, what would type of graph would be a better model?