

The following example has been presented during the workshop on Dec. 6<sup>th</sup>. It based on the undergraduate text book “Physics for Scientists and Engineers” by P. Fishbane, S. Gasiorowicz and S. Thornton, Prentice Hall, 1996, ISBN 0-13-432980-5.

# Example for: laboratory skills.

Physical quantities are never known with exact precision (unless they are merely definitions). We imply a certain degree of uncertainty in a quantity when we assign a certain number of digits to its numerical value. Thus, when we say that an object is 2.00 m long, we mean that it is between 1.995 and 2.005 m long. If we wanted to say that the length is somewhat between 1.9995 and 2.0005 m, we would say that the length is 2.000 m. In the first case, 3 significant figures are used to describe the object's length; in the second case, the number of significant figures is 4.

# Example for: laboratory skills.

Calculations should be reported only to as many significant figures as are contained in the input parameter with the fewest significant figures. The quantity in a calculation that contains the most uncertainty largely dictates the accuracy of the final result. Calculators make it all easy to violate this rule. For example, when asked to calculate the ratio of 3.0 to 11.0, the students might be tempted to write  $0.27272727\dots$ . But in this case, the number 3.0 has the fewest significant figures (2) and thus the reported result should be given with two significant figures, as 0.27.

However, the convention presented in the above example does not fully comply with the convention familiar to the students, as it was indicated to me in the discussions following the Physics Lab. presentation.

The problem with conventions regarding significant figures is easily resolved for measured quantities, if the results are quoted with experimental errors. Examples below discuss the convention which will be used for the Physics Lab. event.

# Example for: error analysis.

For each instrument used in the lab. the students will be expected to estimate its accuracy and, consequently, each measurement performed should be quoted with a relevant experimental error.

The above estimate has to be reasonable. For a number of instruments it is possible to determine the result of the measurement with accuracy better than the smallest increment indicated on the instrument's scale.

# Example for: error analysis.

For example, a meterstick graduated in millimeter marks has a resolution of about 0.5 mm since we can reasonably expect to read the difference between 2.50 and 2.55 cm.

On the other hand, a meterstick graduated in centimeter marks has a resolution of about 1 mm since it is reasonably possible to read the differences on the order of 1/10 of a single mark.

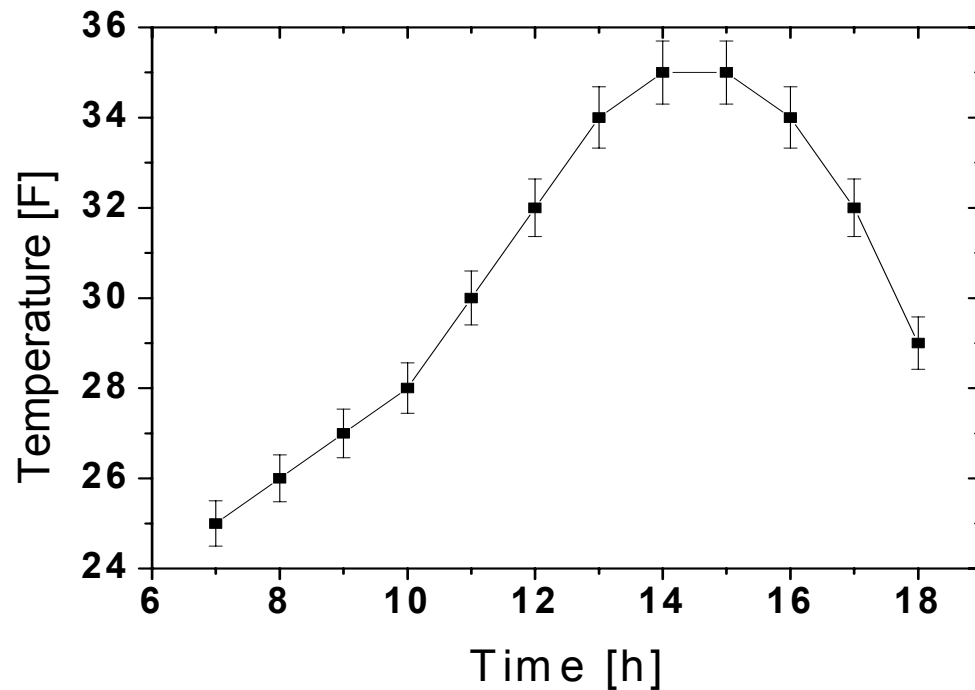
# Example for: error analysis.

The error for the measurement should be quoted with one significant figure. The result of the measurement should be quoted with the same number of decimal places as the experimental error.

For example:  $T=0.937\pm 0.005$  F is quoted correctly, while  $T=0.937\pm 0.05$  F should be quoted as  $T=0.94\pm 0.05$  F.

# Example for: error analysis.

If the graph is used to present the data, the students should plot the data points with experimental errors.



# Example for: error analysis.

If the computation involving measured quantities are required, the experimental errors should be properly propagated to calculate the error for the final result. The convention for quoting the final result is the same as for quoting the result of a single measurement.

**For example, for measured mass  $m=1.23\pm0.02$  kg and volume  $V=1.671\pm0.001$  l the calculated density is:**

$$\mathbf{d=m/V=0.73609 \text{ kg/l,}}$$

**the errors should be propagated as:**

$$(\Delta d/d)^2 = (\Delta m/m)^2 + (\Delta V/V)^2, \quad \Delta d=0.01198,$$

**and the final result should be quoted as :**

$$\mathbf{d=0.74 \pm 0.01 \text{ kg/l.}}$$

The above convention regarding the data analysis should resolve all possible issues concerning significant figures in the Physics Lab. event by relating the number of significant figures to the accuracy of the measurement. If physical constants are needed in the computations, these will be provided by the event supervisor and the number of significant figures for the constants will be indicated.

This handout is posted on Tuesday, Dec. 9<sup>th</sup>;  
in case of any comments or questions, please, e-mail me at [starosta@nscl.msu.edu](mailto:starosta@nscl.msu.edu)