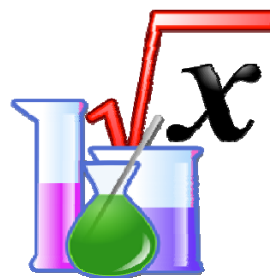


# A. Experimental Practices, and B. Graphing and Analysis with Igor Pro

Week of Sept. 6, 2010

## IGOR Pro

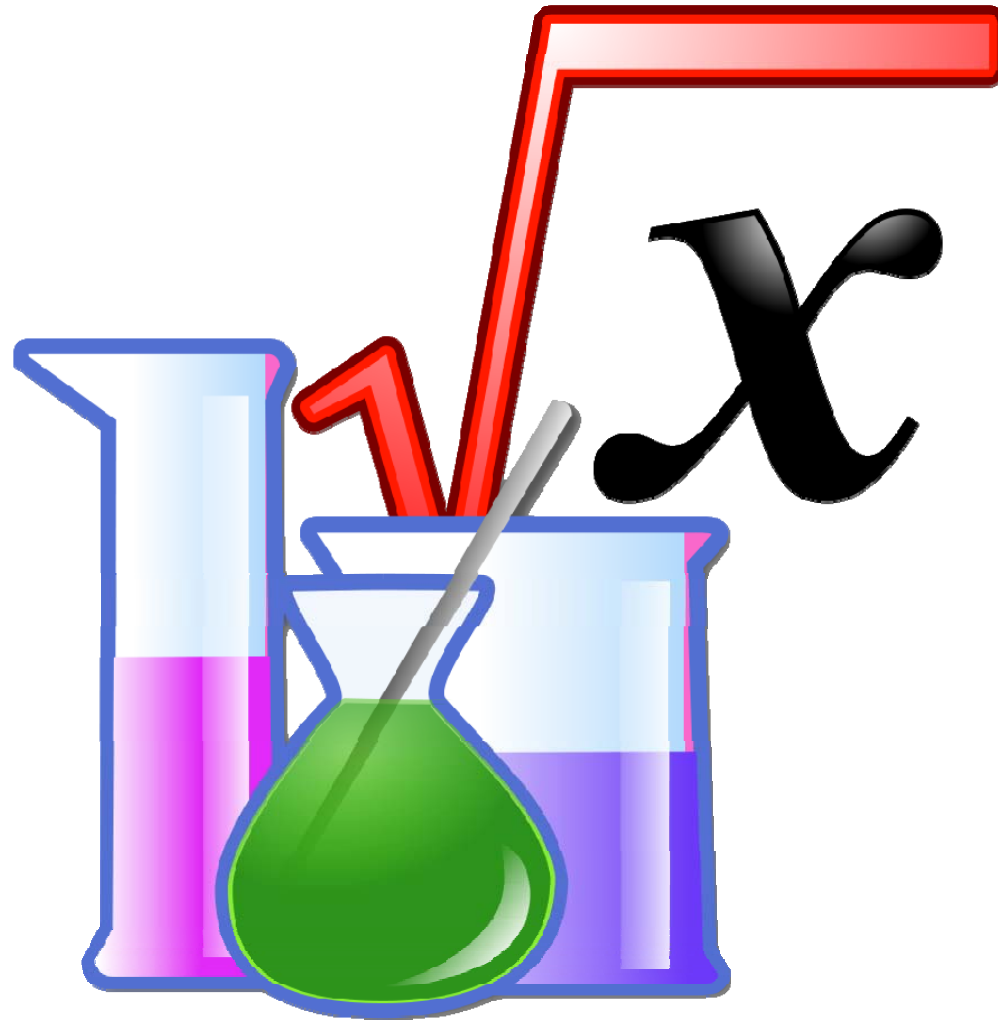
- *Runs on Mac OS X and Windows*
- *Fast Display of Large Data Sets*
- *Interactive Data Exploration*
- *Journal-Quality Graphics*
- *Powerful Curve Fitting*
- *Extensive Data Analysis & Statistics*
- *Image Processing*
- *Data Acquisition Support*
- *Built-In Programming Environment Supports Analysis and Automation*
- *Customizable User Interface*
- *Used by Scientists and Engineers Worldwide Since 1989*



## Atomic and Nuclear Physics Laboratory (Physics 4780)

The University of Toledo  
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# Experimental Methods and Practices



[http://en.wikipedia.org/wiki/Scientific\\_method](http://en.wikipedia.org/wiki/Scientific_method)

# Experimental Methods and Practices

*From sciencebuddies.org:*

## **Key Info**

The scientific method is a way to ask and answer scientific questions by making observations and doing experiments.

The steps of the scientific method are to:

- **Ask a Question**
- **Do Background Research**
- **Construct a Hypothesis**
- **Test Your Hypothesis by Doing an Experiment**
- **Analyze Your Data and Draw a Conclusion**
- **Communicate Your Results**

It is important for your experiment to be a fair test. A "fair test" occurs when you change only one factor (variable) and keep all other conditions the same.

# Key Elements of the Scientific Method

1. Define the question
2. Gather information and resources (observe)
3. Form hypothesis
4. Perform experiment and collect data
5. Analyze data
6. Interpret data and draw conclusions that serve as a starting point for new hypothesis
7. Publish results
8. Retest (frequently done by other scientists)

The iterative cycle inherent in this step-by-step methodology goes from point 3 to 6 back to 3 again.

# Thoughts on the Scientific Method

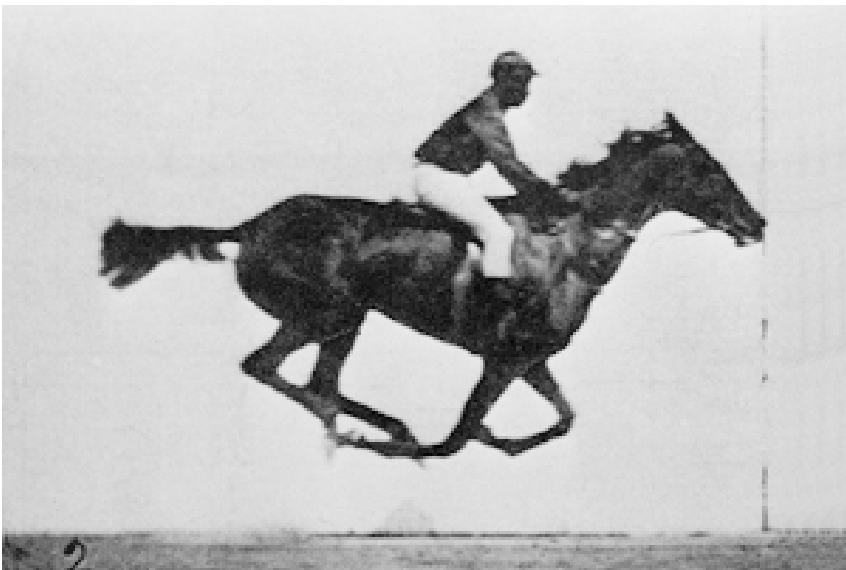
Ibn al-Haytham (Alhazen, 965–1039), pointed out the emphasis on seeking truth:

*Truth is sought for its own sake. And those who are engaged upon the quest for anything for its own sake are not interested in other things. Finding the truth is difficult, and the road to it is rough.*

According to William Whewell (1794–1866), "invention, sagacity, genius" are required at every step in scientific method. It is not enough to base scientific method on experience alone; multiple steps are needed in scientific method, ranging from our experience to our imagination, back and forth.

## Scientific Method: Beliefs and Biases

Eadweard Muybridge's (1830 – 1904) studies  
of a horse galloping



The Epsom Derby (1821) by Géricault, Jean Louis  
Théodore. Oil on canvas.

# Igor Pro 6.1

Mobius - Igor Pro 6.04

File Edit Data Analysis Macros Windows Graph Misc Help Motofit

**Using Igor.hf**

**Data Browser**

The Data Browser is an extension that lets you navigate through the different levels of data folders.

**Procedure**

**Function** makeMobius(pointsx,pointsy,tmin,tmax)  
**Variable** pointsx,pointsy,tmin,tmax

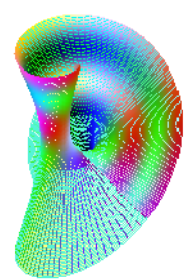
**Variable** i,j,s,arg,ds,tt,dt  
**Make/O/n**=(pointsx,pointsy,3) mobius  
 ds=2\*pi/(pointsx-1)  
 dt=(tmax-tmin)/(pointsy-1)

```

for(i=0,i<pointsx;i+=1)
  s=i*ds
  for(j=0,j<pointsy;j+=1)
    tt=tmin+j*dt
    arg=1+cos(s/2)*tt
    mobius[i][j][0]=cos(s)*arg
    mobius[i][j][1]=sin(s)*arg
    mobius[i][j][2]=tt*sin(s/2)
  endfor
endfor
    
```

End

Gizmo0\_1



- Display TestWave
- Make/O/N=1000 TestWave
- SetScale/i x,0,10, TestWave
- 
- TestWave = Gauss(x,5,1)+gnoise(.01)

**Igor Reference.hf**

**laguerreGauss(p, m, i)**

The LaguerreGauss function returns the normalized product of the associated Laguerre polynomials and a Gaussian. This function is typically encountered in solutions to physical problems where it represents the radial solution with an additional factor  $\exp(i^*m*\phi)$  which is not included in this case. The laguerreGauss is given by

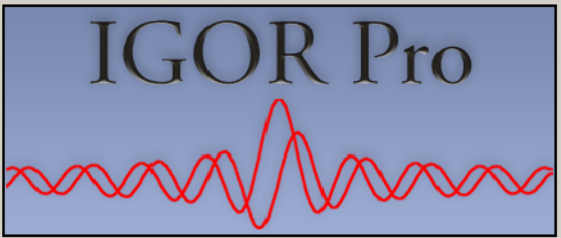
$$U_{pm}(r) = \left[ \frac{2p!}{\pi(m+p)!} \right]^{1/2} (\sqrt{2r})^m L_p^m(2r^2) \exp(-r^2).$$

**See Also**

[Gauss](#), [hermiteGauss](#).

**About Igor Pro**

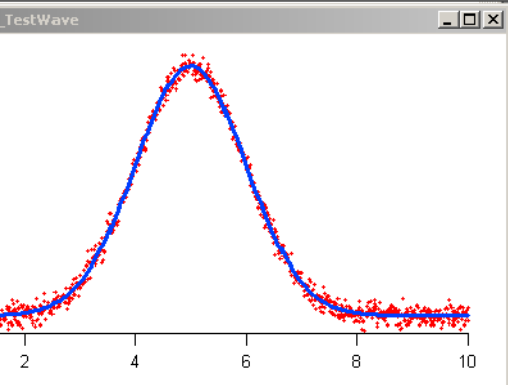
Version: 6.0.4.0



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OK License...

**TestWave**



**StatsCircularTwoSample1**

- StatsCMSSDCDF
- StatsCochranTest
- StatsContingencyTable
- StatsCorrelation**
- StatsDExpCDF
- StatsDExpPDF
- StatsDIPTest
- StatsDunnettTest
- StatsErlangCDF
- StatsErlangPDF
- StatsErrorPDF
- StatsEValueCDF
- StatsEValuePDF
- StatsExpCDF
- StatsExpPDF
- StatsFCDF
- StatsFPDF
- StatsFriedmanCDF

**StatsCorrelation(waveA [, waveB ])**

The StatsCorrelation function computes Pearson's correlation coefficient between two real valued arrays of data of the same length. Pearson r is give by:

$$r = \frac{\sum_{i=0}^{n-1} (waveA[i] - A)(waveB[i] - B)}{\sqrt{\sum_{i=0}^{n-1} (waveA[i] - A)^2 \sum_{i=0}^{n-1} (waveB[i] - B)^2}}$$

Here A is the average of the elements in waveA, B is the average of the elements of waveB and the sum is over all wave elements.

**Details**

If you use both waveA and waveB, then the two waves must have the same number of points.

Ready

# Igor Pro 6.1 (www.wavemetrics.com)

The screenshot displays the Igor Pro 6.10A software interface. The main window, titled 'Getting Started.ihf', contains the following content:

**Getting Started**

This help file contains overview and guided tour material and constitutes an essential introduction to Igor Pro. The main sections are:

- [Introduction to Igor Pro](#)
- [Guided Tour 1 - General Tour](#)
- [Guided Tour 2 - Data Analysis](#)
- [Guided Tour 3 - Histograms and Curve Fitting](#)

We strongly recommend that you read at least the first two sections.

The material in this help file is duplicated in Volume I of the Igor Pro PDF manual which is accessible through the Help menu.

**Introduction to Igor Pro**

Igor is an integrated program for visualizing, analyzing, transforming and presenting experimental data. Igor's features include:

- Publication-quality graphics
- High-speed data display
- Ability to handle large data sets
- Curve-fitting, Fourier transforms, smoothing, statistics and other data analysis
- Waveform arithmetic
- Image display and processing
- Combination graphical and command-line user interface
- Automation and data processing via a built-in programming environment
- Extensibility through modules written in the C and C++ languages

Some people use Igor simply to produce high-quality, finely-tuned scientific graphics. Others use Igor as an all-purpose workhorse to acquire, analyze and present experimental data using its built-in programming environment. We have tried to write the Igor program and this manual to fulfill the needs of the entire range of Igor users.

The interface also shows a 'Table0:' window with the following data:

Unused
Point
0

At the bottom of the window, there is a search bar with the text 'Find Search' and 'Go Back'. The status bar at the very bottom of the screen shows 'Ready'.



## Error handling and propagation

- See handout (to be emailed)
- See also:  
[http://teacher.pas.rochester.edu/PHY\\_LABS/AppendixB/AppendixB.html](http://teacher.pas.rochester.edu/PHY_LABS/AppendixB/AppendixB.html)

## Error (uncertainty) analysis

$$z = f(x, y)$$

$$\Delta z = \frac{\partial f(x, y)}{\partial x} \Delta x + \frac{\partial f(x, y)}{\partial y} \Delta y$$

For uncorrelated errors:

$$\Delta z = \left[ \left( \frac{\partial f(x, y)}{\partial x} \Delta x \right)^2 + \left( \frac{\partial f(x, y)}{\partial y} \Delta y \right)^2 \right]^{\frac{1}{2}}$$

## Error (uncertainty) analysis – example using Activity of $^{241}\text{Am}$ source

$$A = \frac{C}{\frac{\pi s^2}{4\pi r^2}} = \frac{C(4r^2)}{s^2}$$

Where  $C$  is count rate,  $r$  is the distance to the detector, and  $s$  is the radius of the detector.

$$\Delta A = \frac{\partial}{\partial C} \left( \frac{4Cr^2}{s^2} \right) \Delta C + \frac{\partial}{\partial r} \left( \frac{4Cr^2}{s^2} \right) \Delta r$$

$$\Delta A = \frac{4r^2}{s^2} \Delta C + \left( \frac{4C}{s^2} \right) (2r) \Delta r$$

In quadrature, if these errors are uncorrelated:

$$\Delta A = \left[ \left( \frac{4r^2}{s^2} \Delta C \right)^2 + \left( \frac{8Cr}{s^2} \Delta r \right)^2 \right]^{\frac{1}{2}}$$

## Error (uncertainty) analysis – multiple value r.m.s. approach

Another approach to evaluating the uncertainty relies on a straightforward calculation of the root mean square and the standard deviation. In the case of your Activity measurements, you could compute the RMS value as well as the SD. You should still assess your uncertainty through error propagation, as the uncertainty may very well exceed the SD.

Definition of the root mean square from Wikipedia:

“...the [square root](#) of the [arithmetic mean](#) ([average](#)) of the [squares](#) of the original values...”

In the case of a set of  $n$  values  $x_1, x_2, \dots, x_n$ , the RMS value is given by:

$$x_{rms} = \sqrt{\frac{x_1^2 + x_2^2 + \dots + x_n^2}{n}}$$

The **standard deviation** is given as follows, where there are  $N$  values and  $\mu$  is the arithmetic mean:

$$\sigma = \sqrt{\frac{1}{N} \sum_{i=1}^N (x_i - \mu)^2}$$