Due 6/30

Uncertainty and Error

Suppose you read a study in a magazine stating that in the general population 20-30% of people have ear piercings and 1-3% of people have body piercings.

Scientists would write this as
25 +/- 5% of people have ear piercings.
2 +/- 1% of people have body piercings.

The first number is the result, and the second number is the random error in the result (sometimes also called the random uncertainty). Random error indicates how the results might change if you did the survey many times. Usually, if you repeat the survey, your results will agree with the number quoted within the error.

Through most of this course we will ask you to find your uncertainty. Often this is simple enough. If you make a measurement your random uncertainty is the smallest value that you can measure. If you are using a ruler you may be only able to tell things down to the nearest mm. In that case you would record your uncertainty as: +/- 1mm.

Other times you may be recording the "scatter" of your data. For that your random uncertainty is how high above and below an "average" value your data falls. For example you time how many seconds it takes a rock to fall to the ground five times and measure: 5.0, 5.1, 4.9, 5.2, 4.8. You could report this as 5.0 +/- 0.2 seconds.

For this assignment your errors come from sampling a number of things, essentially an error in counting. The error in counting is statistically:

$$\text{error} = \sqrt{\text{number}}$$

As a percentage, the error is:

$$\text{percent error} = 100 \text{ x } (\text{error} / \text{total}).$$

To summarize random error:
- Measurement: smallest measurement one can determine
- Data scatter: amount off of an "average"
- Counting: square root of the number sampled

There is another type of error, *systematic error*. This would be the case if all of your values were too big, or too small, instead of fluctuating up and down. Systematic error often comes from a *bias* in your methods, or equipment, say using a meter stick that isn't really a meter to measure things.

In a few questions you will be asked to compare numbers. To compare two numbers scientifically, you must see if they agree within their respective uncertainties. It's not enough to say that two numbers are close together unless they are within their uncertainties of each other. So the answer to this type of question involves a little math.

To compare two numbers: If $|A - B| <$ | (uncertainty in A + uncertainty in B) | then the two numbers are in agreement.

Notice nowhere do the words ***human error*** show up. Please don't *ever* use them. Instead of listing your source of error as *human*, explain what specifically was the source.

Questions

1. Suppose you want to know if the numbers from the magazine survey on piercings are correct for the population of students at the university. Devise a method to collect a data set to test your hypothesis.
2. How would you revise your plan if you only had two hours to collect the data?
3. Devise an alternate plan in case the observations you want to make are impossible because you are locked in a high tower with no email or cell phone, just a window to look out of.
4. Why can't you include only a small number of people in your sample?
5. What problems might occur if you only chose to look for subjects in a trendy cafe?
6. For questions 2-5 above, explicitly explain why these types of questions are important in astronomy research
7. How are the errors caused by the biases in questions four and five different? Which has a higher random error and which has a higher systematic error?
8. Suppose you collect data on 523 students. If the percentages from the magazine survey are correct (25% and 2%), what numbers of students with each type of piercing do you expect?

9. (4 pts) Here are the hypothetical results from your new survey of 523 university students:

   - 523 Students in total
   - 138 Students with ear piercings
   - 34 Students with body piercings

   Reproduce the table bellow and fill in the percentages of students in your survey with ear and body piercings. Use the correct number of significant figures!

Type of Piercing	% From Magazine	% Error From Magazine	% From Your Survey	% Error From Your Survey
Ear Piercing	25%	5%		
Body Piercing	2%	1%		

10. (2pts) Compare your results with those from the general population that were reported in the magazine study. Keep in mind that the magazine's reported results only have 1-2 significant figures.

    a. Is the percentage of students with ear piercing significantly different from the variation given in the study in the magazine?
    b. Is the percentage of students with body piercings significantly different from the variation given in the study in the magazine?

11. Explain any apparent differences between your new study and the magazine study in terms of possible differences between students and the general population.

12. What new observations could you make that would prove or disprove the existence of the differences you came up with in the previous question?

13. Using the formula given in the background, find the random error in your results. Again, use the correct number of significant digits!

14. Did your study have larger or smaller errors than the one the magazine published?

15. Did the magazine's survey use a larger or smaller sample than yours? (This is a quantitative question, and the answer can be derived from your solutions to question 12.)

16. (3pts) Devise your own scientific test of astrology (the idea that you can predict personalities and fates based on the positions of planets and stars). Clearly define the methods you would use in your test and how you would evaluate the results.

17. (3pts) Science is useful in many aspects of everyday life. Think of a problem or question you encounter in day to day life that you might be able to solve using the scientific method (different from your response to the previous question). What is your hypothesis/model? What testable predictions does it make?