South Western High School

Honors Science Research Project

Procedures & Expectations

AP Biology and AP Physics

Honors Science Research Project Guidelines

1. All students taking any honors or AP level science course are required to complete an approved science research project to receive credit for the course.

2. A student who takes multiple honors or AP level science courses in one school year needs only to complete one project. The student will choose which teacher will serve as the “primary” related to the project requirements and ultimately grade the project.

3. Each teacher has the option to limit the topic for projects to a specific discipline. For example, a chemistry teacher can require that projects relate to a topic in chemistry.

4. **Students are required to submit components of the project as designated by the timeline. Components submitted after the final deadline will be given a grade of zero.** A student is expected to submit his or her project by the deadlines listed on the timeline regardless of that student’s attendance that day. Simply put, being absent on the day that the project is due does not allow the project to be submitted late. If a student will be absent on the day the project is due, he or she must make other arrangements to get the project to school.

5. **Students must earn a 60% on the paper to be considered as successfully completing a project.** Students who earn less than a 60% will be given specific feedback for improvement and must submit a revised project. The original project grade will be the grade used in calculating the course grade.

6. The project grade counts as $\frac{1}{11}$ of the course grade. This compares to each of the two marking periods being $\frac{4}{11}$ each and the final exam being $\frac{2}{11}$ of the course grade:

	FRACTION	POINTS	EXAMPLE
Marking Period 1	4/11	4 x 100pt	4 x 94%
Marking Period 2	4/11	4 x 100pt	4 x 89%
Final Exam	2/11	2 x 100pt	2 x 88%
Science Research Project	1/11	1 x 100pt	1 x 95%
Total	11/11	1100pt	1003/1100 = 91.2%

7. Team projects are permitted, with teacher approval, under the following conditions:
   a. Only students who have successfully completed two individual projects are eligible to be part of a team. In general, this means only juniors and seniors who completed projects as freshmen and sophomores are able to work as a team to complete their project.
   b. The nature of the topic must be such that a team approach is appropriate. In general, this means the project must be of a more challenging nature either in terms of difficulty or time requirements. The primary teacher for the project will have complete discretion to approve or refuse team projects for any reason.
   c. Teams must consist of 2 or 3 students from the same course. No more than 3 students will be permitted.
   d. All team members must sign an intent form. After this, teams may **not** add, remove, or change students.

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Safety First and Above All Else

Science Research Project Outline

-Required Elements-

This section offers a concise outline of the required elements for the science research project. There are many details associated with each section that are explained throughout the packet. Students are strongly encouraged to read the entire packet.

I. Research Notebook

A. Mechanics
1. written in ink
2. numbered pages
3. dated pages
4. legible/organized

B. Parts
1. title page
2. outline of experiment
3. data and results in labeled tables
4. preliminary analysis
5. photographs/diagrams
6. cited resources

II. Research Paper

A. Mechanics
1. title centered on title page
2. double spaced
3. typed
4. written in past tense
5. written in passive voice
6. correct internal citations
7. each section clearly labeled
8. experimental procedure in paragraph form
9. tables consecutively numbered
10. graphs consecutively lettered

B. Parts
1. introductory paragraph
    a. significance of project cited
    b. choice of topic explained
2. review of literature (relevant research discussed)
3. hypothesis
4. experimental procedure
5. data and results
    a. tables and graphs
    b. statistics
    c. focused on hypothesis

6. discussion and analysis
7. conclusion
8. applications and extensions
9. acknowledgments
10. literature cited
    - *a. minimum of six valid sources*
    - *b. two recent periodicals*
    - *c. sources relevant to topic*
    - *d. proper format and layout(APA)*

III. Oral Presentation

A. Introduction
1. Project Title
2. Background
3. Purpose for choosing project

B. Experiment Section
1. Hypothesis
2. Experimental procedure
3. Variables

C. Results Section
1. Presentation of results
2. Identification of trends
3. Discussion of error

D. Conclusion Section
1. Conclusions drawn
2. Value of work explained
3. Extensions

E. Question and Answer Period

IV. Abstract

A. Header
B. Hypothesis stated
C. Brief background stated
D. Purpose stated
E. Procedure described
F. Essential data summarized
G. Essential statistical analysis included
H. Conclusion stated
I. Applications indicated

Science Research Project
-Overview-

1. **Pick your topic**. Get an idea of what you want to study. Ideas might come from hobbies or problems you see that need solutions. Due to limited resources of time and money, you may want to study only one or two specific events.

2. **Research your topic**. Go to the library or Internet and learn everything you can on your topic. Observe related events and get hands-on experience as early as possible. Look for unexplained or unexpected results. Also, talk to professionals in the field, write or e-mail companies for specific information and obtain or construct needed equipment.

3. **Organize**. Organize everything you have learned about your topic. At this point you should narrow your area of research by focusing on a particular idea. Your research should help you.

4. **Make a timetable**. Choose a topic that not only interests you but also can be done in the amount of time you have. Allow plenty of time to experiment and collect multiple trials of data. Even simple experiments do not always go as you might expect the first time or even the second time. Leave time to write your paper and develop your oral presentation.

5. **Plan your experiment**. Once you have a feasible project idea, write an experimental procedure. This plan should explain how you will do your experiment and exactly what it will involve. Your procedures should be designed to vary your independent variable and measure your dependent variable while controlling all other variables that could affect your results. Multiple trials are expected. The exact number of trials you need to complete will depend on your particular experiment. *Please discuss the required number of trials with your teacher*.

6. **Conduct your experiment**. You must receive approval from your teacher prior to collecting data. During experimentation, keep detailed notes of each and every experiment, measurement, and observation. Do not rely on your memory. Change only one variable at a time and make sure to include control groups in which none of the variables change. Make sure you include sufficient numbers of test subjects in both control and experimental groups. A group must have five or more subjects to be statistically valid. Not all experiments require a control group.

7. **Examine your results**. When you complete your experiments, examine and organize your findings. Did your experiment give you the expected result? Why or why not? Was your experiment performed with the exact same steps each time? Are there other explanations that you had not considered or observed? Were there errors in your observations? Remember that understanding errors and reporting that a suspected variable did not change the results can be valuable information. Statistically analyze your data.

8. **Draw conclusions**. A conclusion is a factual summary of the experiment. Which variables are important? Did you collect enough data? Do you need to conduct more experimentation? Keep an open mind. Never alter results to fit a hypothesis. If your results do not support your original hypothesis, you still have accomplished successful scientific research. An experiment is done to support or refute a hypothesis.

(Step #1)
-Selecting A Topic-

Selecting a topic for your science research project is probably the most difficult step. However, if you begin your search with a field of science in which you are already interested, this first step will be greatly simplified. The kind of project you need is one that produces **MEASURABLE DATA**. Your project **must** deal with an effect that can be measured with **NUMBERS AND UNITS**. The best project poses a question and use scientific techniques to answer it.

Newspapers, science magazines, and science television programs offer many ideas for science research projects. Your parents may also have some ideas for you. Topics may be found in the many books and magazines in your school library and in your science classroom.

You are going to spend several months working on this project so choose a topic that is interesting to you. What aspect of science would you like to know more about? Is there a topic that relates to your future career plans? Be cautious about using topic suggestions from websites or books; they are often too simple or do not actually involve an experiment.

(Step #2)
-Refining A Topic-

Once you have decided on a topic, you will have to develop a science project. A science project deals with causes and effects. You may want to compile a list of causes and effects for your topic with which you can work.

In your project, you will change one factor in order to observe its effect on some other factor. The factor you change is the independent variable (the cause). The result obtained after manipulating the independent variable is the dependent variable (the effect). Usually there is only one independent variable in high school science projects.

Please note that both the independent variable and dependent variable must be measured or recorded. You may need to develop operational definitions for your variables in order to refine your topic. An operational definition explains how a particular variable will be measured. For instance, if your variable is the temperature of a piece of metal, then your operational definition might be "the temperature of the metal will be determined by using a non-contact infrared thermometer". Since there are multiple ways to measure any given variable, the operational definition both refines the topic and makes your experiment reproducible.

Once you have chosen your topic and received approval from your teacher, continue to read about your topic. An intensive review of all related literature is basic to all scientific research. To develop a quality project, you will need additional knowledge of the concepts and principles fundamental to your research, current information on the subject, and scientific support for your idea. You will need to document the accepted facts, concepts and processes upon which the research is based. Your search of the scientific literature will enable you to find an area that is not well known or completely researched.

(Step #3)
-Taking Notes-

Organized notes make writing and drawing conclusions easier. This will be done in your RESEARCH NOTEBOOK. The requirement for taking notes in your research notebook are:

1. Use a bound, composition-style notebook.
2. Always use ink.
3. Write “Research Notes” and your name on the cover of the notebook.
4. Begin your notebook with a title page.
5. Include a “Table of Contents” that is filled in as work progresses.
6. Number the pages and write the date on which you recorded the notes on each page or section.
7. Record ALL data and research in the notebook. Consider it a daily logbook which contains all data and observations ***as well as reflections or thoughts***.
8. Record the reference information for each new source.
9. Write complete ideas. Be concise and clear. You may use abbreviations and your own shorthand.
10. When recording data, draw tables or charts and fill it in.
11. Copy striking statements and put them in quotation marks. This will allow you to use them later, if applicable and give proper credit to the author.
12. Go beyond written sources of information. Include research done by *interacting with the equipment or subjects* that will be part of your experiment. Get "hands-on" as early as possible and record preliminary findings.
13. Include at least **six sources** of information by the due date.
    - Two of the sources must be recent periodicals

(Step #4)
-Writing the Hypothesis-

All scientific research must have a definite purpose or hypothesis. What question are you trying to answer? What experimental data are you seeking? You can only obtain limited answers in one science project. Be sure you limit your hypothesis to a goal that you can attain. Be sure your hypothesis reflects a “testable” statement. Avoid the use of ambiguous terms such as “best.” You must have a clear understanding of what you will be measuring to determine the “best.”

The hypothesis of your project should be stated in one sentence and describe a cause-effect relationship. Difficulty in accomplishing this indicates the need for further refining or narrowing of the project. A general form can be used to state your hypothesis:

> **If the** *independent variable* **is** *increased/decreased*, **then the** *dependent variable* **will** *increase/decrease*.

Simply substitute your specific independent and dependent variables into the hypothesis. Your choice of increased or decreased should be based upon your review of literature and preliminary research. In other words, the hypothesis stands alone but is supported by your research presented in your review of literature. The hypothesis can be clarified by including operational definitions in your experimental design.

The hypothesis is a specific type of prediction that relates the independent and dependent variables. Your experiment will be designed such that it controls all factors other than the independent and dependent variables so that a relationship can be established. Your data and analysis will either *support* or *refute* your hypothesis, it will not *prove* anything. There is no penalty if it turns out that your data refutes your hypothesis. In scientific research it is often more common to design a hypothesis and experiment such that the hypothesis is refuted. The basic idea being that it is "easier" to show what *cannot be* than what *must be*.

(Step #5)
-Experimental Design-

A successful science research project requires a good deal of careful planning. This planning will enable you to avoid some of the difficulties and to keep your project on track. Some things to consider as you design your experiment are:

1. determining the equipment you will need.

   Check with your teacher to find what items are in stock. It is your responsibility to find what you need. It is to your benefit to get your hands on equipment or specimens as early as safely possible.

2. identifying your independent variable.

   The cause of the change in your research is the independent variable. During your experimentation, you will vary one factor to observe what will happen. The factor you vary is the independent variable. For your experiment to be valid, you will need to sufficiently vary the values of your independent variable. In most cases, this will be five variations. *Include an operational definition of your independent variable*.

3. identifying your dependent variable.

   You change one factor to observe what will happen to something else. The "something else" is the dependent variable. *Include an operational definition*.

4. controlling variables.

   Only the independent variable is changed in a controlled experiment. All other factors must be kept constant and are called "controlled variables." This is often the major challenge in experimental design.

5. control groups*.

   Controlled experiments are designed to determine cause and effect. There must be a standard to which the experimental data can be compared. A control group is free of any change (free of the independent variable). In many, but not all experiments*, you will need to have a control group in order to compare the results of the experimental group.

6. determining a logical sequence of steps to carry out your experiment.

   a. Your procedure must include in detail, everything you will do in your project. Your procedure must be sufficiently detailed so as to allow another researcher to exactly duplicate your project by following your written plan. SAFETY at all times!

   b. The experimental procedure, when written in your RESEARCH NOTEBOOK, can be in list or paragraph form.

   c. Use past tense, passive voice when writing the procedure.
   ("*The solution was mixed*." instead of "***I will*** *mix the solution*.")

d. No separate listing of materials needs to be made. Materials will be incorporated into the procedural steps.

e. The test subjects (living things) must be identified by common name and scientific name. The scientific name is written in italics or underlined. The first word of the scientific name (the genus) is capitalized. The second word of the scientific name (the species) is not capitalized.

f. Specify the source of the test subjects.

g. Specify the exact type and brand of any specialized equipment.

7. multiple trials

An experiment is designed to collect data. The more data that is collected, the more confident you can be in your results. A trial is performed under a specific value of the independent variable and the resulting value of the dependent variable is measured. Since something unexpected could happen during any given trial, multiple trials must be conducted and the recorded values for the dependent variable can be averaged together. **If an experiment needs 10 trials, then the exact same thing is done 10 times.** After that, the independent variable can be changed and another 10 trials could be conducted at that value of the independent variable.

(Step #6)
-Experimenting-

During your project, you may be working with materials and equipment that can cause injury if not handled properly. Before beginning your lab work, read the following safety rules, learn them and adhere to them. SAFETY at all times!

General Rules

1. Perform only those experiments previously approved by your teacher.
2. Keep your work area clean and uncluttered.
3. Wear safety goggles when working with flames, chemicals or preserved specimens.
4. Know the location of the fire extinguisher, eyewash station and safety shower.
5. Have all apparatus checked out by your teacher before use.
6. Use the correct tool for each job.
7. Keep combustible materials away from heat and flame.
8. Clean up all spills immediately.
9. Report all accidents immediately to your teacher or your parents.
10. Experiments involving fumes or vapors must be conducted in a fume hood.
11. Do not view LASERS, the sun, ultraviolet lamps or other lights directly.

Biological Precautions

1. Use only nonpathogenic bacteria and fungi.
2. Wear rubber gloves when working with bacteria.
3. Kill all cultures of bacteria and fungi before disposing of them. Do this in an autoclave or sterilizer.
4. Make sure you follow all rules that apply to working with vertebrate animals.

Chemical Precautions

1. Use only chemicals you have obtained from your teacher.
2. Read and double-check all labels on chemical bottles.
3. Avoid touching chemicals.
4. Do not use unlabeled chemicals.
5. Do not return unused chemicals to stock bottles.
6. Never taste chemicals.
7. Use of known or suspected carcinogenic chemicals is strictly regulated. Ask your teacher.
8. Pour acid into water. Never pour water into acid.
9. Never mix chemicals without prior clearance from your teacher.

(Step #7)
-Recording Data-

Data must be recorded in tables in your RESEARCH NOTEBOOK as it is collected. The data from these tables will later be put into graphs and analyzed.

Rules for Data Tables

1. The title of the table names the dependent variable first and the independent variable second.
2. The title clearly indicates the relationship between the two variables.
3. The title shows the unit of measure utilized.
4. Each column of the table must be labeled with the appropriate information.
5. Tables must be consecutively numbered.
6. A brief caption should be included with each table.

Some sample tables are shown on page 15.

Rules for Graphs

1. A graph requires a brief but specific explanation as a title.
2. The two axes of the graph must be labeled with the variable represented and the units of measurement. (ex. Distance (cm.))
3. Generally, the independent variable is on the X-axis and the dependent variable is on the Y-axis.
4. Each axis is subdivided to form a numerical scale of equal intervals so that the total range of expected values is shown along the axis.
5. Point protectors and error bars should be used appropriately.
6. Study the pattern made by your data points. If they form a curve, draw the "best fit" curve by drawing a curve smoothly that passes through or close to all the plotted points. If the data points form a straight line, draw the "best fit" line that passes through or close to all the plotted points. Do not simply "connect the dots"; look for patterns.
7. If you have a "straight line" graph, the equation for the line must be included.
8. Graphs must be consecutively lettered (figure A, figure B, figure C, etc.).
9. Bar graphs should not be used. Graphs should be line graphs and can be produced using the scatter plot feature in Microsoft's *Excel.*
10. A brief caption should be included with each graph.
11. There are computer programs that will turn your data into graphs and conduct most of the statistical analysis. Microsoft's *Excel*, PASCO's *DataStudio*, and Vernier's *Graphical Analysis*, are all available for your use at school.

Visit http://office.microsoft.com/en-us/excel/HA010548401033.aspx for detailed instructions for creating a scatter-plot graph in Excel.

A sample graph is shown on page 16.

Uncertainty in Data

Any data recorded in the laboratory should always be accompanied by an estimate of its uncertainty. This uncertainty can be expressed as an error range, a relative error, or a percentage error.

Example: The temperature read from a thermometer that is graduated to 0.1 ^{o}C would be recorded as:

error range

Take half the value of the smallest readable unit. Add & subtract this value from your data point.

$$25.0 \pm 0.05\ ^{o}C$$

relative error

$\pm$ 0.05 / 25 = $\pm$ 0.002

percentage error

($\pm$ 0.05 / 25) x 100 = $\pm$ 0.2%

Sample Calculations

You must include a sample calculation for every unique type of calculation performed. **You <u>do not</u> need to show sample calculations for common types of calculations like calculating the mean value or standard deviations.**

Example: Sample Calculation 1 - The following is a sample calculation of the density of water using data from table 3:

$D = {}^{m}/_{V}$ where: *D=density, m=mass, and V=volume*

D = 13.6 g / 13.5 mL *using data from trial 1*

D = 1.01 g/mL

The remaining values of density were calculated in a similar manner.

Sample Data Tables

Table 1- Time (s) vs. Temperature (10 °C)

Trial	Temperature (°C)	Time of chemical reaction (s)	Absolute Deviation
1	10	180	0
2	10	180	0
3	10	179	1
4	10	173	7
5	10	192	12
6	10	175	5
7	10	183	3
8	10	189	9
9	10	187	7
10	10	188	8
11	10	172	8
12	10	171	9
13	10	175	5
14	10	175	5
15	10	180	0

Mean = 180
Mean Deviation= 5
% Deviation = 3%

Table 1 displays the data taken for the chemical reaction taking place at a temperature of 10 (°C).

Table 2 - Mean Time (s) vs. Temperature (°C)

Temperature (°C)	Mean Time of chemical reaction (s)
0	200
10	180
20	163
30	147
40	130
50	108
60	91
70	73
80	51
90	45
100	42

Table 2 displays the calculated mean time for the chemical reaction to run to completion at several temperatures.

Sample Graph

Figure A

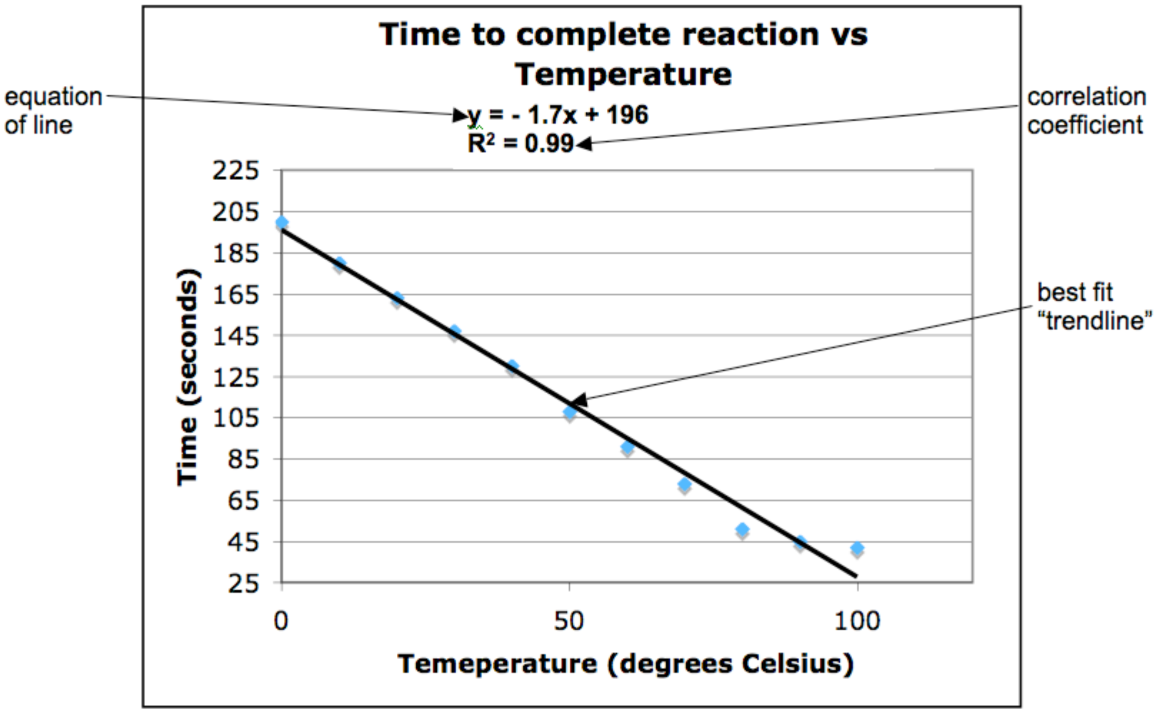

Figure A displays the mean time for the chemical reaction to run to completion at each of the temperatures used. The reaction of the calcium carbonate was considered complete when there was no more bubbling present in the Erlenmeyer flask. The equation of the line indicates that the time decreased by 1.7 seconds for every 1 degree increase in temperature. The R^2 value of 0.99 indicates that the data are very close to a linear relationship.

(Step #8)
-Error Analysis-

Types of Errors

1. *Systematic Errors*: Systematic errors result from faulty calibration of a measurement device, misapplication of a measurement technique, or use of an inappropriate mathematical model. An example might be reading the mass from a balance that was not zeroed.

2. *Random Errors*: Random errors result from a large number of unknown and unpredictable variations in measurement. They include the effects of observer judgments in deciding when and how to read scales, temperature fluctuations and mechanical vibrations.

3. *Careless Errors*: Careless errors are made by inattentive observers who misread graduated glassware, copy data incorrectly and make mistakes in mathematical calculations. These errors are totally avoidable and must be eliminated.

For more complete information concerning statistical analysis of data we recommend the following book: Carr, Joseph J. ***The art of science: A practical guide to experiments, observations, and handling data***. San Diego: High Text, 1992.

Steps in Basic Statistical Error Analysis

1. Calculate Mean Value
2. Calculate Absolute Deviations
3. Calculate Mean Deviation
4. Calculate Relative or Percent Deviation
5. Calculate Percent Error or Difference (if appropriate)

1. Calculate Mean Value

When you collect data, often you collect a series of measurements in multiple trials and then use the mean value in your analysis. The mean is often referred to as the "average" value but this use of the word "average" is not totally correct.

In order to calculate the mean value from a series of measurements you simply need to add all of the values together and then divide that sum by the number of values. We indicate a mean value by drawing a line above the variable.

mean = sum of values ÷ the number of values

$$\bar{x} = \frac{\sum_{1}^{N} x_i}{N}$$

2. Calculate Absolute Deviations

Any set of numbers can be added together and a mean value calculated, but that does not imply that finding the mean value is always useful or meaningful. In order to help determine how useful or reliable the mean value is, we examine deviation.

Absolute deviation is simply finding how "far" each measurement is from the mean value. If you have *five* measurements of length, then you will have *five* separate deviations, calculated by:

Absolute Deviation = individual value - mean value

$$Absolute\_Deviation(x) = |x_i - \bar{x}|$$

3. Calculate Mean Deviation

This simply requires that you add up all of your absolute deviations and then divide by the number of values in your sample. This number indicates the "average" amount of variation in your data set.

Mean Deviation = sum of absolute deviations ÷ number of values

$$Mean\_Deviation = \left(\frac{1}{N}\right)\sum_{1}^{N}|x_i - \bar{x}|$$

4. Calculate Relative or Percent Deviation

Relative deviation or percent deviation is a number that tells you how "well" all of your data fits the mean value. Another way to think of relative deviation is that it measures how "closely packed together" all of your data is. To calculate relative deviation, you first calculate each absolute deviation and then calculate the mean deviation as described above. You then divide the mean deviation by the mean value and multiply by 100 to turn it into a percentage. (a more rigorous analysis would use **standard deviation** if your data permits)

%Deviation = (mean absolute deviation ÷ mean value) x 100

$$\%Deviation = \left(\frac{\left(\frac{1}{N}\right)\sum_{1}^{N}|x_i - \bar{x}|}{\bar{x}}\right) \times 100$$

5. Calculate Percent Error or Difference (if appropriate)

The first four steps above compare values within a given set of trials to determine the precision of data collected. In order to determine accuracy you could calculate percent error which compares your experimental mean value to an accepted or theoretical value. Percent difference is used when you simply compare two values to determine how similar they are.

$$\%Error = \left(\frac{|\text{accepted value} - \text{experimental value}|}{\text{accepted value}}\right) \times 100$$

$$\%Difference = \left(\frac{|\text{value\#1} - \text{value\#2}|}{\left(\frac{|\text{value\#1}| + |\text{value\#2}|}{2}\right)}\right) \times 100$$

Example of Mean and Deviation:

The following mathematical calculations will be shown using sample data from an experiment attempting to determine the molar mass of carbon dioxide.

Data: *(this example only uses three trials...)*

Trial 1: M_1 = 42.35 g/mole
Trial 2: M_2 = 41.69 g/mole
Trial 3: M_3 = 44.03 g/mole

Mean = sum of the values ÷ the number of values

= (42.35 + 41.69 + 44.03) ÷ 3 = 42.69 g/mole

Absolute deviation = l individual value – mean value l

D_1 = l42.35 – 42.69l = 0.34 g/mole
D_2 = l41.69 – 42.69l = 1.00 g/mole
D_3 = l44.03 – 42.69l = 1.34 g/mole

Mean Deviation = sum of absolute deviations ÷ number of values

= (0.34 + 1.00 + 1.34) ÷ 3 = 0.89 g/mole

Relative Deviation = (Mean Deviation ÷ Mean) x 100

%D = (0.89 ÷ 42.69) * 100 = 2.1%

The lower the %D the more *precise* your data appears to be.

(Step #9)
-Writing the Research Paper-

The purpose of your research paper is to persuade the reader that the conclusions you have drawn are correct. This goal can be accomplished if you write clearly and concisely. **Label each section**.

1. **Title Page**

The title should be specific and describe what you are studying.

2. **Introductory Paragraph and Review of Literature**

The *first paragraph* of your introduction (introductory paragraph) should capture the interest of a reader knowledgeable about the field of study. Explain your choice of the topic, particularly if you had an interesting personal reason, and discuss the overall significance of your topic. Conclude the introductory paragraph with a clear, concise statement of the purpose your research was done, that is, the specific question you are trying to answer.

In the next few paragraphs, describe the research of other scientists that specifically relate to your project. Discuss how this present experiment will help to clarify or expand the knowledge in this general area. All background information that you have gathered from other sources must be appropriately referenced. Your goal is to lead the reader towards your hypothesis statement, not just paraphrase information or fact, therefore your writing style should be focused and purposeful. This *Review of Literature* should "funnel" from broad concepts to the specific relationship that your hypothesis deals with.

Use internal citation as needed and be sure to have a complete list of literature cited. Only information cited throughout the body of the paper should be listed in the literature cited section of the paper. See example below for the correct internal citation format. Any information you use in your research paper that is not information you have actually obtained yourself and is not general knowledge *must include* a reference to indicate the source of that information. This is referred to as "citing the reference."

Internal Citation Format: *Citations are extremely important (Author, Publication year).*

Example: *Science research can be a rewarding experience (Smith, 2010).*

For additional examples, visit www.swsci.weebly.com .

3. **Hypothesis**

The hypothesis must be a complete, single sentence. It must follow the form described earlier in the packet. No other explanation is needed with the hypothesis because it should be a natural consequence of the *Review of Literature*.

4. **Experimental Procedures**

This is where you describe the procedure for your experiment. It should be in paragraph form and as always, in past tense, passive voice (avoid using *"I"* or *"me"*). The rule to keep in mind is this: the experimental procedure section should be detailed and clear enough so that any reader would be able to duplicate the experiment.

<u>Clearly indicate</u> the independent variable, dependent variable, control variables and the control group (if needed). Use the term experimental group for your test group. Provide *operational definitions* for the independent and dependent variables. An operational definition helps clarify a variable by describing how it will be measured.

If any work was done outdoors in a natural habitat, describe the study area, state its location and explain when you did the work. If any specimens were collected for the study, state where and when they were collected. **Photographs and diagrams must be used as an aid in describing your procedure.** Test subjects should be identified by common name and scientific name. The scientific name must be either underlined or written in *italics*. The first word of the scientific name is capitalized but the second word is not. Be sure to describe any special techniques used. Specify the exact type and brand of any special equipment used.

5. Data and Result

The results must be presented in a straightforward manner, with no conclusions or value judgments as to what the data might mean. If possible, the data should be assembled into tables and graphs to make it more easily understandable. Tables and graphs must be accompanied by a narrative text. The text describes the results that are presented in the tables and graphs and calls attention to what you consider to be the significant data that you will talk about in *Discussion and Analysis*. Graphs should summarize data and show trends or patterns, especially if they connect to the hypothesis. Include the **sample calculations** and make sure they are labeled.

The numerical uncertainty of your data should be stated as well as your statistical error analysis. For linear relationships, *include the equation for the line*, the meaning of the slope of the line, mean square error or correlation coefficient. For nonlinear relationships you may need to use more advanced software in order to determine the significance of the data. *DataStudio* and *Graphical Analysis* are two programs that will make graphing your data more productive and insightful.

Tables and figures (graphs, pictures, drawings, maps etc.) are assigned numbers and letters on the basis of the order in which they are first mentioned in the text. The first table to be mentioned is "*table 1*", the second is "*table 2*" etc... The first figure to be mentioned is "*figure A*", the second is "*figure B*" etc... Tables are always labeled at the top and figures are always labeled at the bottom. Each table and graph must be clearly and completely titled, labeled, scaled and have the units marked. Tables and figures can be placed as close as possible to the actual page where the table or figure is mentioned in the text.

6. Discussion and Analysis

Explain what you think the results mean. Describe any patterns that emerged, any relationships that you think were meaningful and any correlations that you could determine. This includes any explanations as to why you think the results turned out differently from the way you expected or why the results were either different from or similar to the information already known about the problem. *Refer to your data as well as the mathematical calculations your performed*. Have your results occurred by chance or are your findings significant? Describe what went wrong during your first trials and also cite any sources of error. Discuss issues related to accuracy and precision. Make conclusions about the meanings of the data and explain why you have reached those conclusions. In effect, you are defending your point of view.

7. Conclusion

The conclusion should be first stated in one sentence that parallels your hypothesis in content and grammatical structure. Discuss whether your hypothesis is **"supported"** or **"refuted"** by the results of your research. This section is a partial repeat of the Discussion and Analysis. Simply state again all the conclusions but without any of the reasons as to why you reached these conclusions. This section presents all the important conclusions and significant discoveries that you want the reader to know. In effect, the Conclusion section enables the reader, if he/she doesn't have time to read the entire paper, to quickly determine what you have discovered. The Conclusion section is, in a sense, a capsule version of the Data and Results and Discussion and Analysis. By looking at just the Introduction and Conclusion sections, a reader should have a pretty good idea of what you have done although he/she might not know the details of how the work was done.

8. Applications and Extensions

The implications of your research are explained in this section. Judges often like to see that your research has some specific value to life (industry, farming, water quality, etc.). Extensions include any improvements that could be made in the procedures to reduce sources of error. Suggest other interesting ideas for further investigation in future studies. Your Review of Literature may help you in writing this section.

9. Acknowledgments

This section gives the names of all the people who helped you with your project. Include parents, teachers and other professionals who assisted you.

10. Literature Cited

This section lists, in alphabetical order, all published information that was referred to anywhere in the text of the paper. Note that the literature cited includes only the references that were actually mentioned in the paper. Any other information that the researcher may have read concerning the problem but did not mention in the paper, is not included in this section. Follow current APA standards for creating this section. If you are unfamiliar with APA, the SWHS library has resources that can help you and there are several websites that may help as well.

Visit the SWHS Science Research Project Webpage (www.swsci.weebly.com) for instructions on how to create your literature cited page, as well as links to online citation builders.

(Step #10)
-Writing the Abstract-

An abstract is a condensed summary of your entire project. Scientists write an abstract as an easy way to share the results of their research with the scientific community. At one page in length, an abstract can allow the reader to figure out if the research is of interest to them. Use your abstract to convince the reader that your research was of sufficient interest to have undertaken it. The abstract must include the following:

MECHANICS

1. paragraph form
2. double spaced
3. past tense, passive voice
4. approximately one page in length

PARTS

1. header with title, your name and address included
2. hypothesis stated
3. brief background stated
4. purpose stated
5. procedure described
6. essential data summarized
7. essential statistical analysis included
8. conclusion stated
9. applications indicated

Your research notebook and paper contain all of the data, analysis, and discussion that you would need to defend your project to "scientific" peers. Your backboard will summarize your notebook and paper. The abstract, in turn, condenses your project even further.

See sample abstract on page 24

Sample Abstract

Effects of Marine Engine Exhaust Water on Algae
Jones, Mary E.
123 Main Street, Hometown, PA 20920
South Western High School, Hanover, PA

The hypothesis of this project is that the toxicity of two-cycle marine engine exhaust will decrease the population of green algae. This project in its present form is the result of experimentation on the effects of two-cycle marine exhaust water on certain green algae. The initial idea was to determine the toxicity of engine lubricant. Some success with lubricants eventually led to the formulation of "synthetic" exhaust water which, in turn, led to the use of actual two-cycle engine exhaust water as the test substance.

Toxicity was determined by means of the standard bottle bioassay technique. *Scenedesmus quadricauda* was used as the test organism. Toxicity was measured in terms of a decrease in the maximum standing crop. The concentration of exhaust water effective at reducing the population of *Scenedesmus quadricauda* was found to be 3.75%.

Anomalies in growth curves raised the suspicion that evaporation was affecting the results; therefore, a flow-through system was improvised utilizing the characteristics of a device called a Biomonitor. Use of a Biomonitor lessened the influence of evaporation, and the effective concentration was found to be 1.4% exhaust water with a relative deviation of 2.3%.

The contributions of this project are twofold. First, the toxicity of two cycle marine engine exhaust was found to be considerably greater than reported in the literature (1.4% vs. 4.2%). Secondly, the benefits of a flow-through bioassay technique utilizing the Biomonitor was demonstrated.

(Step #11)
-Planning Your Project Presentation-

In order to practice presentation skills that are necessary for scientists to share their research results with the wider scientific community, you will be expected to prepare and deliver an oral summary of your project. The purpose of your project presentation is to briefly share with a panel of teachers what you have learned through your research experience. The oral presentation should be at least 6 minutes but no more than 8 minutes in length. At the conclusion of your presentation, the panel will ask questions about your project to determine your level of understanding of the research project. The entire time allotted for your presentation and questioning will be 15 minutes.

The oral presentation should include, at minimum, a visual representation of your results in the form of a summative graph. You are encouraged to provide other visual components to enhance your presentation such as a Keynote or PowerPoint presentation, or slides created using other software presentation like Google Presentation, Prezi.com or Voicethread.com.

The oral presentation should include the following parts:

I. Introduction
   A. Project title and research question
   B. Brief background and purpose for choosing project
   C. Hypothesis

II. Experiment and Results
   A. Description of experimental procedure
   B. Results (Data Tables)
   C. Identification of trends (Summative Graph)
   D. Discussion of error and its effect on results

III. Conclusion
   A. Hypothesis supported or refuted
   B. Conclusions drawn
   C. Value of work explained
   D. Ideas for improvement or further work

* Visit www.swsci.weebly.com to view the rubric for the oral presentations.

Your science teacher will explain the procedures for signing up for a time slot, obtaining a pass to leave class at your presentation time, submitting your presentation to Dropbox, and scheduling a make-up time for your presentation if you absolutely can't be in school on the presentation day.

A digital or hard copy of your presentation (slides, graphs, etc.) is due to your teacher at the scheduled time of the presentation if you are not in school**. If you are absent due to illness, you must e-mail a copy of your presentation to your science teacher by the scheduled start time of your presentation in order to receive credit for this portion of the project.** Students must complete a presentation in order to receive credit for the class however late presentations will receive a grade of 0% and factor into the overall grade for the project.

Some hints for developing a good oral presentation are:

Before the presentation:

- Make sure your oral presentation has a good introduction and conclusion. In addition to framing the presentation, this provides a natural way to ease in and out of the serious scientific report. You'll be able to speak in friendlier manner and add some of your own personality to the presentation. (But not too much personality. This is a science presentation after all, not a comedy show—keep it professional.)
- Practice, practice, practice. Practice in front of the mirror, in the shower, whenever you have time and wherever you see fit. Ask for parents or relatives to take turns listening. If no one's available, a teddy bear or family pet makes a great captive audience.
- Ask a friend to practice with you. Take turns listening and asking questions.
- Practice in front of your visual presentation and with any additional visual aids. Practice pointing to relevant features, and make sure your audience can see what you're pointing to.
- Time your oral presentation to ensure it's within the time limit allowed.

At the presentation:

- Be yourself.
- Wear something comfortable yet professional.
- Make eye contact with the panel. Maintain eye contact when not reading notes.
- Avoid saying "uhm" and "like."
- Don't chew gum.
- Don't talk too quickly. If you catch yourself racing ahead, take a deep breath and slow down.
- Pay attention to your posture and body language. Stand up straight and try not to fidget.
- Be serious, but not stiff.
- Use gestures to emphasize the most important points.
- Be honest—if you don't know the answer to a question, it's okay to say so. Scientists and teachers will tell you they don't know all the answers either.
- Show enthusiasm for your subject!

- Science Research Project -
-AP Biology and AP Physics Time Line -

Due Dates	What's Due	What You Should Be Working On
Check Website	time window opens for topic selection discussion on moodle	choosing a topic
		choosing a topic / researching
	topic selection	researching / review of literature
		researching / review of literature
	research notebook w/ 6 sources & preliminary notes submitted	designing a hypothesis with independent / dependent variables
		hypothesis / writing review of literature
		designing experimental procedures
	review of lit/hypothesis submitted	testing and refining procedures
	experimental procedures submitted	experimenting
		experimenting
		experimenting
		experimenting / analyzing data
		analyzing data/writing research paper
	data tables submitted	writing research paper
	summative graph submitted	finishing paper
		finishing paper
		finishing paper/write abstract
	research paper, abstract, & self assessment due by 8:20 AM*	preparing oral report
	project presentation (by appointment) research notebooks due at presentation	

<u>*Project components submitted after this time will not be graded.</u>
If you are not in school that day due to illness or other circumstance, it is your responsibility to make arrangements so that the stated deadline is met.

<u>* Research Notebooks will be checked each time a component of the project is submitted</u>

South Western Science Research Project
Paper Evaluation Tool

Introductory Paragraph & Review of Literature
- significance of project cited ☐
- choice of topic explained ☐
- relevant research discussed ☐☐
- supports and explains hypothesis ☐☐
- focused from broad to specific ☐☐

Hypothesis
- clear/unambiguous ☐
- testable ☐
- cause & effect relationship ☐
- concise, one sentence ☐

Experiment/Procedures
- independent variable identified ☐
- dependent variable identified ☐
- variables controlled effectively ☐☐
- independent variable sufficiently altered ☐☐
- pictures/diagrams with descriptive text included ☐
- appropriate measurements taken ☐
- quantitative data taken ☐
- paragraph form ☐

Data/Results/Analysis

Tables
- data and statistics in tables ☐
- tables titled and labeled ☐
- proper units/sig figs used ☐
- narrative included ☐

Graphs
- data in graphs (line graph/scatter plot) ☐
- graphs titled and labeled ☐
- graph units indicated ☐
- narrative included ☐
- summative graph included ☐

Calculations
- statistical analysis completed ☐
- deviations calculated ☐
- proper units/sig figs used ☐

Analysis & Conclusion
- *supported* or *refuted* used ☐
- hypothesis content & grammar paralleled ☐
- deviations explained ☐
- trends identified and supported ☐☐☐
- predictions made and supported ☐
- sources of error discussed ☐☐
- effect of errors on results discussed ☐☐

Applications & Extensions
- specific value of work explained ☐
- improvements mentioned ☐
- ideas for further work suggested ☐
- rationale for improvements/further work included ☐☐

Mechanics
- title centered on title page ☐
- double spaced ☐
- written in past tense ☐
- written in passive voice ☐
- correct internal citations ☐
- each section clearly labeled ☐
- acknowledgements included ☐

References & works cited
- minimum of six valid sources ☐
- two recent periodicals used ☐
- proper format and layout ☐

Quality Points

A. Level of difficulty

simple	1.0
moderate	2.0
challenging	3.0
extremely challenging	4.0

B. Overall quality

Justification:

poor	1.0
acceptable	2.0
high	3.0
outstanding	4.0

C. Score for number of trials

none evident	0.0
insufficient	1.0
adequate	4.0
ample	5.0
exceptional	5.5

(A + B) x C = Quality Points

☐ ☐ ☐ ☐

40 possible

TOTALS

Quality points ☐ ***40 points***

Completion points ☐ ***60 points***

Total points earned __________out of 100 points possible

Student________________________________

South Western Science Research Project
Research Notebook Assessment

Mechanics	Each box worth 0.5 points
written in ink	[ ]
pages numbered and dated	[ ]
legible	[ ]
organized	[ ]
Required Elements	
title page	[ ]
experiment outlined	[ ]
all data recorded in tables	[ ]
tables labeled	[ ]
pictures/diagrams included	[ ]
descriptive text included with pictures/diagrams	[ ]
Effective use of research notebook *Should contain all research and data, both quantitative and qualitative, related to project and essentially serve as a daily log or journal during all phases of the project*	**Score 1-2-3-4-5**
Total	**/10**

-

Abstract Assessment

Mechanics	Each box worth 1 point
double spaced and paragraph form	[ ]
past tense, passive voice	[ ]
one page in length with header	[ ]
Required Elements	
hypothesis stated	[ ]
background and purpose stated	[ ]
procedure described	[ ]
data summarized with statistical analysis	[ ]
statistical analysis included	[ ]
conclusion stated	[ ]
applications indicated	[ ]
Total	**/10**

Research Paper Total _____/100

Notebook Total ______/10

Abstract Total ______/10

Oral Presentation Total ______/40

Total Score ______/160

Instructions for Posting to Moodle

In an effort to provide an opportunity for peer-to-peer collaboration among all honors science students, you will be asked to post various parts of your project to an online discussion forum in Moodle. See the science fair timeline for more information about when postings are required.

1. Go to http://swmoodle.swsd.k12.pa.us
2. Click on Science under the High School heading.
3. Click on Honors Science Research Project
4. If this is the first time you have used Moodle, you will be required to set up a user profile by following the on-screen instructions.
5. To enroll in the course, you will need to enter the one time enrollment key.

    ENROLLMENT KEY: swhs

6. Click on the appropriate forum.
7. Click on "Add a new topic discussion" and follow the on-screen instructions.
8. After you have posted, you may click on other posts and leave responses by clicking "reply".

Access to Online Rubric for Oral Presentations

BEFORE you present, you must do the following:

1. Go to www.RCampus.com
2. Select [create login] on top
3. Choose Student/Learner and click [continue]
4. Create login information, and press [continue]
5. Complete your profile, and press [save]
    **How did you hear about us? Choose "other" and write "friend"
6. From top menu select [classroom]
7. From side menu select [join class]
8. Enter the following codes:
    Class ID: See Teacher or Science Research Project Website
    Access Code: (press the spacebar so that there is a space, but nothing else)

Once you have completed these steps, your account will be active and visible to your teacher.

AFTER you present, you can view your completed rubric and presentation grade by doing the following:

1. Log-in using the username and password you created above
2. Click on the [classroom] tab
3. Click [grades]
4. Select current class from the "Class" drop-down menu

You should now see a summary of your grade. To see the detailed rubric, click on the blue and white icon under Rubric/Quiz.