How to do Science – a reference manual

<u>Scientific Method – Terminology</u>

Observation = something that you observe with your 5 senses. It might be a measurement (qualitative) or a description (qualitative).

Inference = an interpretation of what you observed.

Variable = something (factor, trait or condition) that can change (vary) in an experiment.

Independent variable = the factor, trait or condition that the experimenter changes. As the experimenter, **<u>I</u>** control this.

Dependent variable = the factor, trait or condition that is observed.

Controlled variable = a factor, trait or condition that stays constant throughout all experimental trials.

A proper experiment only changes one thing so that it can be determined if this one thing causes a change. For example, if I want to see if temperature affects the bounce of a basketball, the one <u>independent</u> variable would be temperature. The <u>dependent</u> variable would be the bounce of the basketball. Likely I would measure the height that the basketball rebounds to off the floor. I would want to keep everything else the same, for example: the brand of basketball, the floor I am using, the initial height of the drop etc. So brand, floor and drop height are <u>controlled</u> variables.

If I changed the temperature and used different brands of basketball and I saw a change in the bounce, I wouldn't know if the difference was due to temperature or if one ball is just inherently more bouncy than the other.

<u>Scientific Method</u> http://www.lasciencefair.org/method.htm

There are definite steps to conducting a scientific inquiry. Essentially you ask a question or pose a problem and set about in an organized fashion to try and discover the answer. The basics steps for a scientific inquiry are (in order):

Purpose: A statement describing what is to be determined. It can be written as a question. Often the purpose comes from observing something and wondering about it.

ie: I notice basketballs left in the trunk of my car in January don't bounce so well.

My purpose might be: Is there a relationship between temperature and the amount of bounce of a basketball?

Hypothesis: This is an educated guess about the results you expect.

ie: It is predicted that as the temperature of the basketball is reduced, the amount of bounce will decrease. A direct correlation is predicted.

Materials & Method: This is where you outline how the experiment will be run. The idea is to provide a 'recipe' for another person to repeat your experiment exactly as you do. A result is considered more valid if more than one person can run the experiment and get the same results. So it is important that this section is precise.

Materials needed are listed in bullet form much like a cookbook recipe.

The method is outlined in numbered steps (#1, #2, #3….). A labelled diagram can be included and often helps the reader understand more clearly.

Observations: Here you record what you observed. This is 'raw' data. These observations can be **quantitative** (measurements) or **qualitative** (descriptive statements). Often the results are expressed as a graph and/or a table of results (data). *Refer to sections on 'data tables' and 'graphs' for more detail.

Analysis: Analysis is composed of calculations and thoughts about results.
You may need to do some calculations with your raw data. This new information is called 'calculated' data and sometimes it is helpful to put it into a data chart too. Include a sample calculation for each type of calculation you do, showing complete solutions and all units. Use GRASP method of solving math problems.

You may also be discussing your results here (especially if it is an experiment you designed) and/or answering assigned questions (if a school lab).

Conclusion: What did you discover? Remember your purpose was to ask a question or solve a problem. Here you state your conclusion. A reader should be able to look at the purpose and then skip to the conclusion and appreciate the question and the answer to that question.
More advanced conclusions will explain, justify, theorize and discuss experimental error. You may explain how you arrived at your conclusion(s). You may justify your method and describe your results. It is relevant at times to suggest a theory to support or interpret your results. This is the appropriate place to discuss any source of experimental error which would have affected your results. Published work often suggests in the conclusions the future direction of the research. Perhaps a question was answered but more questions arose. That's awesome science!

Note about experimental error – Do not list human sloppiness as 'experimental error'. For example, I might have done the calculations incorrectly, leading to an error in my results. Errors in measuring are also poor. ie: I may not have measured the mass properly. When you are performing an experiment, be careful. It is good to redo measurements to see if you are precise. Make sure your math is done correctly.

<u>Writing up a Lab Reports for Science</u> Note: It is preferred that this be done on a computer.

Set-Up

1. Use a separate page to write up each lab report.
2. Write headings on a separate line. Title is centred. Subtitles are aligned to the left.
3. Underline each heading.
4. Skip a line between each section.
5. Write in pen or process with a computer.
6. Use the following format. **Note**: name etc. is aligned to the right of page.

Your Name

Partners' Names

Date of experiment

Period

<u>Title of Experiment</u>

<u>Purpose</u>:
Skip a line and write your purpose here.

<u>Hypothesis</u>:
Skip a line and write your hypothesis here.

<u>Materials</u>:
Do not list if you are performing an <u>assigned</u> investigation. Your statement instead should be "Refer to lab handout or lab manual." Note any changes. ie: Note: sodium chloride was replaced with sodium fluoride.

If you are preparing your own investigation, all materials need to be listed.

<u>Procedure</u>:
Do not recopy if you are performing an assigned investigation. Your statement should be "Refer to lab handout or lab manual." Note any changes.

If you are preparing your own investigation, all steps in the procedure must be described. Remember to write this in numbered steps, past tense, and passive voice.

<u>Observations</u>:
Present your data in tables, graphs or illustrations, each with a title. *See section on data tables and graphs. There may be some written observations as well.

<u>Analysis</u>:
Skip a line and add the analysis.

<u>Conclusions</u>:
Skip a line and add the analysis.

Language Skills

1. Use complete descriptive sentences. Point form, slang/jargon and incomplete sentences are not acceptable.
2. Write each lab in the third person. Do not use 'I' or 'you'.
3. Proper grammar and spelling is expected for each report.

More advanced…
More advanced lab reports may contain some background research. If this is needed, I will provide more information in class. If references are required, please refer to the section on APA referencing.

<u>Data Tables: How to create a good one</u>

#1 - Simple Example:

Track & Field Results

Student	Long jump distance **(m)**	Triple jump distance **(m)**	100 m time **(s)**
George	1.2	5.5	12.1
Sally	1.1	4.5	11.9
Beth	1.3	5.0	12.5
Don	1.1	6.8	12.0
Archie	0.9	5.6	12.2
Average results	1.1	5.5	12.1

Sample calculation of average:
For long jump: 1.2 + 1.1 + 1.3 + 1.1 + 0.9 / 5 = 1.1 m average for long jump

<u>**Note**</u>: → nice straight lines (by computer or with ruler!)

- ➔ The **title** on top of the chart! It should tell the reader what the chart is about.
- ➔ **Units** are listed at top of column in round brackets. ie: (m)
- ➔ <u>Units are NOT included</u> in the body of the chart
- ➔ Use of different line styles to separate title from data (double lines) and average results from individual results (darker line). Although not essential, this is nice!
- ➔ Sample calculation below. You do NOT need to include all calculations. Include one sample from each type of calculation to show you know how to do it. That's it.

#2 - Example with more calculations:

Kinetic Energy of Various Objects

Object	Mass (kg)	Speed (m/s)	Kinetic Energy (J)
Baseball	0.5	10	25
Gol f ball	0.25	12	18
Soccer ball	0.7	6	13
Average kinetic energy			

Sample Kinetic Energy Calculation:
m = 0.5 kg $E_k = \frac{1}{2} mv^2$
v = 10 m/s   Ek = ½ (o.5)(10)(10) = 25 Joules

Sample average calculation:
25 + 18 + 13 / 3 = 19 Joules

<u>**Note**</u>: → if there are 2 or more different types of calculations, you need to include a sample of <u>each</u> type to show you know what to do.

➔ I had to measure mass and speed before I could calculate kinetic energy. Thus, mass and speed are considered 'raw data' – I measured it. Kinetic energy is considered 'calculated data' – I did not directly measure it. I calculated it based on raw data. Always put ***raw data*** in the chart **BEFORE** the ***calculated data***. This is the order in which you did it.

#3 - More complex example (showing multiple trials and an average)

Size of radius	**Time for 3 cycles (s)** Trial #1	Trial #2	Trial #3	Average time (s)
Small	2.5	2.7	2.4	2.5
medium	4.7	4.4	4.8	4.6
Large	6.1	5.9	6.5	19

Sample average calculation:
For small radius: 2.5 + 2.7 + 2.4 / 3 = 2.5

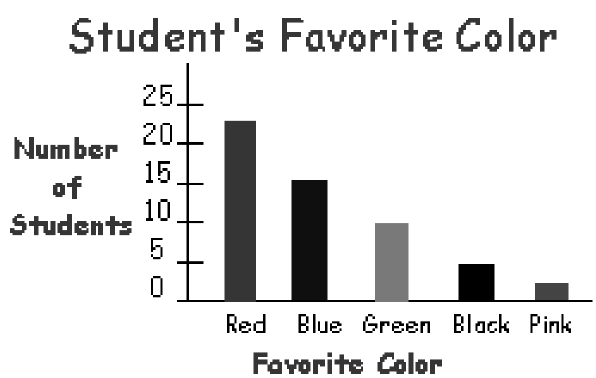
Note:
➔ How 1 title (time for 3 cycles) is above 3 columns.

Graphs: How to Draw & Analyze Graphs

Graphs are a great way to display your results. Often the scientist varies one aspect (independent variable like favourite colour) and observes the outcome (dependent variable like # of students). Which graph you choose depends on whether these variables are qualitative or quantitative.

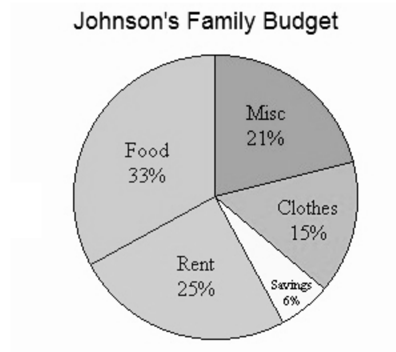
As a general rule, the independent variable goes on the x axis and the dependent variable goes on the y axis.

Bar Graphs: When one of the variables being graphed is qualitative (not a number), bar graphs are a good way to go. Follow the rules for Point-and-Line graph when drawing. Refer to page 618 in text.



http://www.enchantedlearning.com

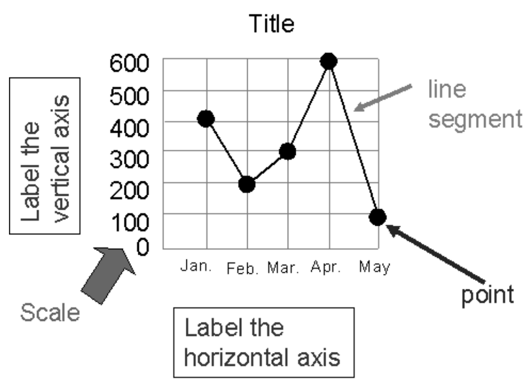
Circle Graphs: Circle graphs are used in situations similar to bar graphs in that there is one set of qualitative values. If you can translate the quantitative values to a <u>percentage</u>, the circle graph is a nice way to go. Refer to page 618 in text.



http://flipquiz.me

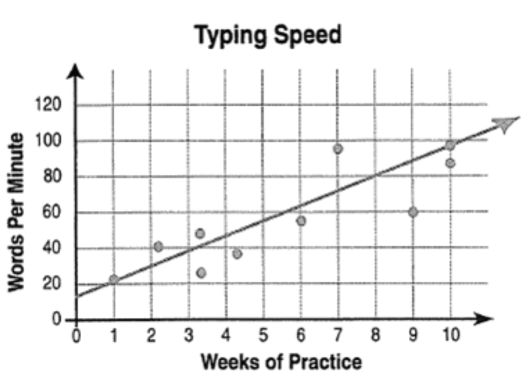
Line Graph: This kind of graph is used when both quantities are quantitative. If you are using a computer to graph the results, it may not be possible to follow all the rules. Refer to page 619 in text.

1) Use plain <u>pencil and a ruler</u>.
2) <u>Use graph paper</u>. Don't skimp. Larger graphs are easier to interpret.
3) Usually the <u>independent variable</u> goes on the <u>'x' axis</u>. The <u>dependent variable</u> goes on the <u>'y'axis.</u> The exception is when you have 'time' as a variable. It is always on the x axis. Label parallel to axes.



http://www.studyzone.org/

4) <u>Determine the range</u> for each axis. ie: find the lowest → highest values and make sure they will fit. Often a little extra room is left.
5) <u>Plot your points</u>. <u>Connect</u> the points. If it looks better to do a <u>line of best fit</u>, then do so. If you are plotting more than one set of data, you can use different coloured <u>pencil</u> or use different symbols for the points. (• * Δ etc.) . Note: sometimes the 'line of best fit' is actually a 'curve of best fit'.This is tricky to do by hand but graphing programs can do. **If there's a line of best fit, you can determine the formula of the line. **

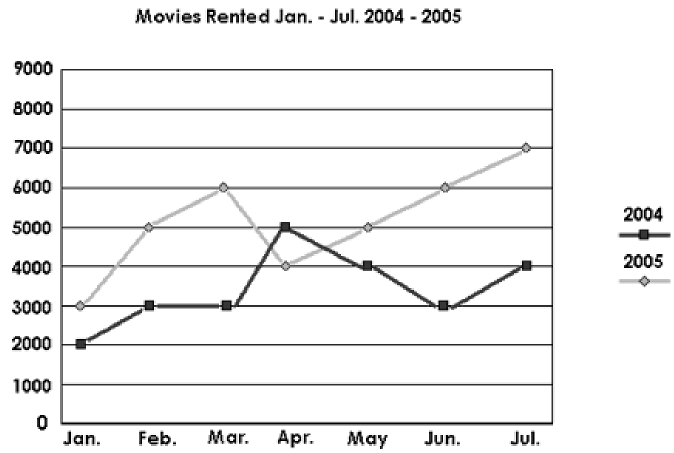


This shows a line of best fit.

http://madaboutscience.weebly.com

This shows 2 sets of data on the same graph. Notice how symbols are used to differentiate and a legend is supplied.

http://openhighschoolcourses.org

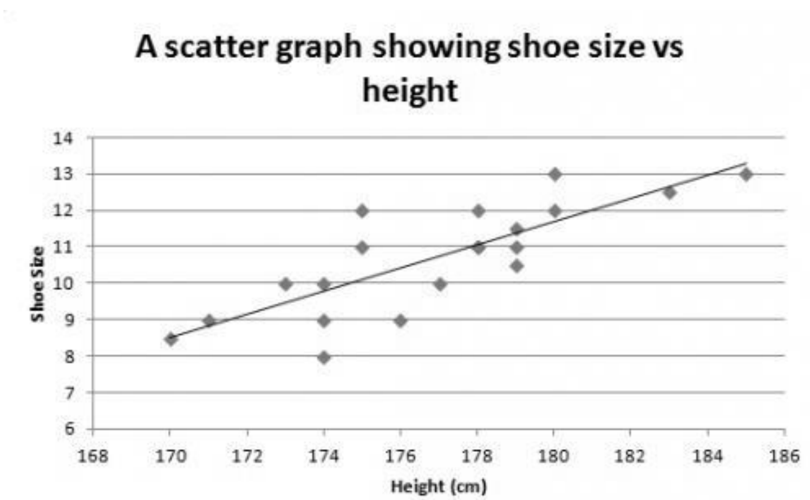


6) Title your graph after it is drawn. It should be placed within the axes and the title should reflect what is on the 'x' and 'y' axis. I prefer a boxed title (with a ruler). The reason for placing title within the x & y axes and boxing it is so that it is very evident. Often students place a unboxed title high above the graph and it is not notice.

Note: Most often in physics we are looking for a trend and a line of best fit is the way to go!

Describing a graph: Describing a bar graph (favourite colour was red, followed by blue) and a pie graph (food and rent were the biggest costs in the Johnson's budget) and usually pretty straight forward. Describing a line graph with a line of best fit is a little more involved.

Positive correlation = This describes a graph in which the y-axis variable increases as the x-axis variable increases. ie: one gets larger as the other gets larger.

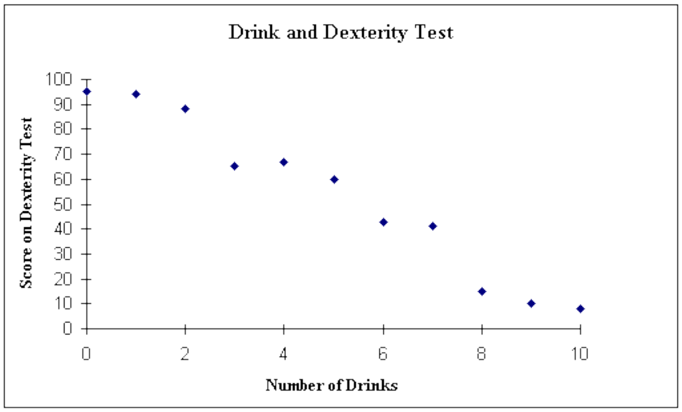


We say: As height increases so does the shoe size. (Makes sense!)

Notice the results are not perfect. There is some scatter & this is to be expected with real results.

http://cribbd.com

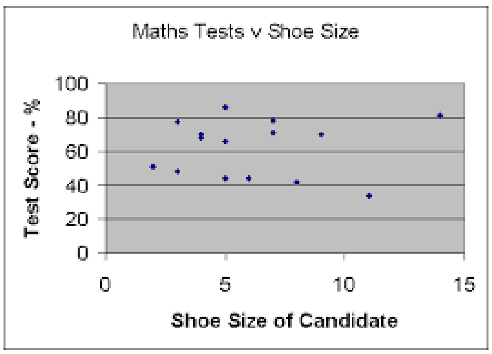
Negative correlation = This describes a graph in which the y-axis variable decreases as the x-axis variable increases. ie: one gets smaller as the other gets bigger. The example below does not have a line of best fit but you could easily draw one in.



We say: As the number of drinks increases, the dexterity of the individual decreases. (Makes sense! This is why we don't drink and drive)

https://records.viu.ca/~johnstoi/maybe/maybe4.htm

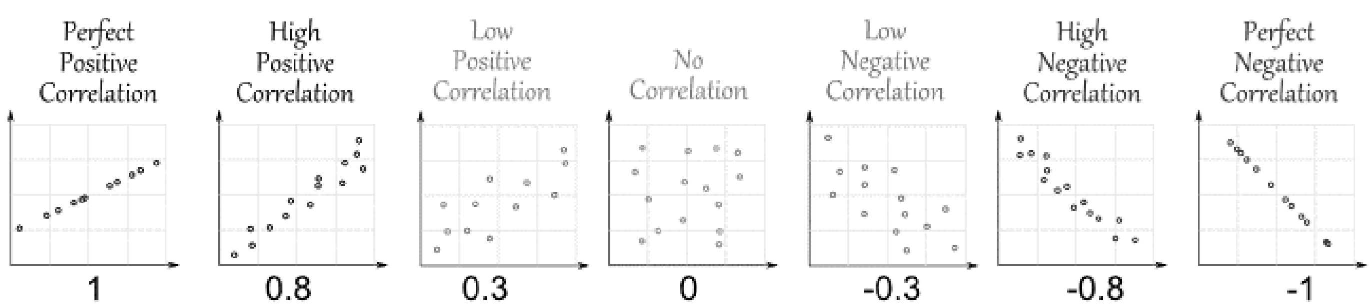
No correlation = This describes a graph in which there is no discernable relationship between the x & y axes. It appears random.



We say: This is no apparent correlation between shoe size and math scores. (Makes sense!)

http://www.google.ca

Degrees of correlation: The image below says it best!



https://www.mathsisfun.com/data/scatter-xy-plots.html

Careful: All scientists need to be careful with analyzing results. A graph of grade in elementary school versus height would show a positive correlation. (One normally moves up a grade as you age and as you age you normally grow in height and your feet grow – hence the increased show size). Grade and shoe size would be positively correlated but this does not mean that one causes the other. Moving up a grade in school does NOT cause your feet to grow. So there is always critical thinking required when it comes to thinking about & analyzing experimental results. Sometimes more experiments are required!

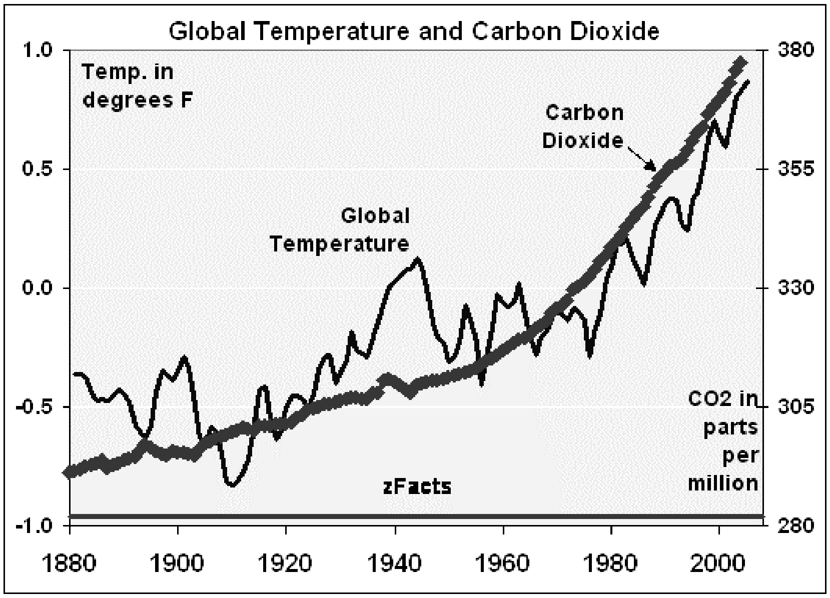
Correlations = co-related = variables together.

Causal = describes a relationship when one factor <u>causes</u> the other. Ie: we believe that an increase in CO_2 gas is driving (causing) global warming.

Research

APA

APA In-text



Notes

Referencing

C http://www.science20.com

GRASP: Solving Mathematical Problems

Use the GRASP method to solve mathematical problems

G – Givens – List the information you are given. Sometimes there is information you are assumed to know. For example, it is expected that you know acceleration due to gravity is 9.8 m/s^2.

A sketch or diagram is helpful (and encouraged) here.

R – Required – List what you are required to find. What is the question asking for?

A –Analysis – How are you going to solve the problem?

You can list formulas you need to use and/or list steps.

S – Solve – Plug the numbers into the formulas and solve.

P – Paraphrase – write the solution out clearly in a full sentence.

Be neat & clear. Do not crowd your work.

Significant Digits

Note: the following has been copied from https://www.physics.uoguelph.ca/tutorials/sig_fig/SIG_dig.htm

The number of significant digits in an answer to a calculation will depend on the number of significant digits in the given data, as discussed in the rules below. *Approximate* calculations (order-of-magnitude estimates) always result in answers with only one or two significant digits.

When are Digits Significant? → Non-zero digits are always significant. Thus, 22 has two significant digits, and 22.3 has three significant digits.

→ With zeroes, the situation is more complicated:

a. Zeroes placed before other digits are not significant; 0.046 has two significant digits.
b. Zeroes placed between other digits are always significant; 4009 kg has four significant digits.
c. Zeroes placed after other digits but behind a decimal point are significant; 7.90 has three significant digits.
d. Zeroes at the end of a number are significant only if they are behind a decimal point as in (c). Otherwise, it is impossible to tell if they are significant. For example, in the number 8200, it is not clear if the zeroes are significant or not. The number of significant digits in 8200 is at least two, but could be three or four. To avoid uncertainty, use scientific notation to place significant zeroes behind a decimal point:

8.200×10^3 has **4** significant digits
8.20×10^3 has **3** significant digits
8.2×10^3 has **2** significant digit

Significant Digits in Addition and Subtraction

When quantities are being added or subtracted, the number of *decimal places* (not significant digits) in the answer should be the same as the least number of decimal places in any of the numbers being added or subtracted.

Example:

5.67 J (two decimal places)
1.1 J (one decimal place)
0.9378 J (four decimal place)
7.7 J (one decimal place)

Keep One Extra Digit in Intermediate Answers

When doing multi-step calculations, *keep at least one more significant digit in intermediate results* than needed in your final answer.

For instance, if a final answer requires two significant digits, then carry at least three significant digits in calculations. If you round-off all your intermediate answers to only two digits, you are discarding the information contained in the third digit, and as a result the *second* digit in your final answer might be incorrect. (This phenomenon is known as "round-off error.")

The Two Greatest Sins Regarding Significant Digits

1. Writing more digits in an answer (intermediate or final) than justified by the number of digits in the data.

2. Rounding-off, say, to two digits in an intermediate answer, and then writing three digits in the final answer.

Short Answer Responses

There are 3 key components

- Start by putting some of the question in the answer. (Q in A).
  ie: Question: What is your favourite colour? Answer: My favourite colour is blue.

- Give a supporting fact or detail
  ie: I always have at least 3 blue t-shirts in my dresser.

- Add some explanation.
  ie: I think I like blue so much because it reminds me of the water and sky and I like to be outdoors.

Oral Presentations

Make sure to face the audience & speak loud enough for the back of the room to hear you. If you need to refer to the board and/or a visual aid, try not to turn your back to the audience. Practise and pace yourself. Sometimes when we are nervous we speak very fast. It is ok to use cue cards but strive to use them minimally. Put point form statements on them. You may even get to the point where you just have subtitles there to guide your discussion.

Slideshows

When presenting a slide show make sure to face the class, not the slide. Use the slides as cue cards to guide your discussion. It is always helpful to refer to the slide. For example, you can point to a particularly useful picture to help you explain.

Some other aspects of a strong slideshow presentation

- first slide is a title slide. It is best if it has a picture and your name.
- second slide should be an 'outline' slide that outlines what you will cover in the slideshow. This is usually the 'sub-topics' of your presentation.
- background & font are uniform
- colour is not hard on the eyes or distracting. ie: pink text on a yellow background is distracting **and** hard on the eyes.
- font is large enough to see from back of room – typically 30+
- a picture on most/all slides
- point form information *You are the presenter. Don't put down full sentences or (gasp!) paragraphs. You invite your audience to simply read the slide and ignore you.
- small amount of information at once. If your slide has a lot of information, consider chunking it and revealing a bit at a time.
- avoid distracting animation.
- titles and subtitles should be in a larger font that the regular text

Posters/Brochures etc.

How your poster/brochure looks is part of this kind of format. Plan our how you will use all the space first.

- negative space - You should strive not to be too crowded and not have a lot of blank space. The space you don't use is called 'negative space' and you want just enough. You also want your negative space to be balanced ie: not all on one side of the poster. It should be somewhat symmetrical.
- font size – The title should be the biggest and the subtitles the next biggest. The titles and subtitles should stand out.
- spelling and grammar – There should be no errors here. Make sure to proof read.
- pictures – part of the reason to create a poster or brochure is to include visual aids. Choose pictures that clarify what you are saying. Don't just put in 'filler' pictures. There should be a reason to put them there. Make sure to refer to the pictures. ie: the inside of a laser contains …………..and these can be seen in Figure #1 below.
- Neat – You can do posters/brochures using the computer or by hand. If doing by hand, make sure writing is neat and straight. You may need to draw some faint pencil lines in with a ruler and erase when you are done. Use pen! If printing photos to be attached to your work, use glue and make sure all edges are secure. Do NOT use tape and/or staples. Tape looks ugly and staples allow edges to curl up.

Plagiarism

Plagiarism is the act of using another person's words or ideas without giving credit to that person. (www.meriam-webster.com). It is essentially theft and is not allowed.

Examples of plagiarism:

- copy & paste from the internet
- copying your partner's work
- taking information from a published source that is not common knowledge and not acknowledging source.

Your work should sound like you. You are encouraged to research and find relevant information but credit must be given to the source. This information must be rewritten in your own style.

Research Notes

When researching, it is a good idea to copy down the date and the source at the top of the page. Underneath you can write down key ideas in point form and in your own words. You can also add sketches and/or diagrams. By fragmenting the information this way you prevent yourself from plagiarizing. Do NOT take notes verbatim from a source. If you don't understand something, don't use it. Find a simpler explanation of this information elsewhere. If you think the information is vital to your task, you can seek help from a teacher or librarian or other knowledgeable person.

APA Formatting

In science writing, APA (American Psychological Association) format is preferred. Please refer to this link provided for a 'cheat sheet' of how to do this: http://www.library.kent.edu/files/APACheatSheet.pdf

It is also helpful to use internet sites to help you format your references. Consider: http://www.bibme.org or http://www.noodletools.com