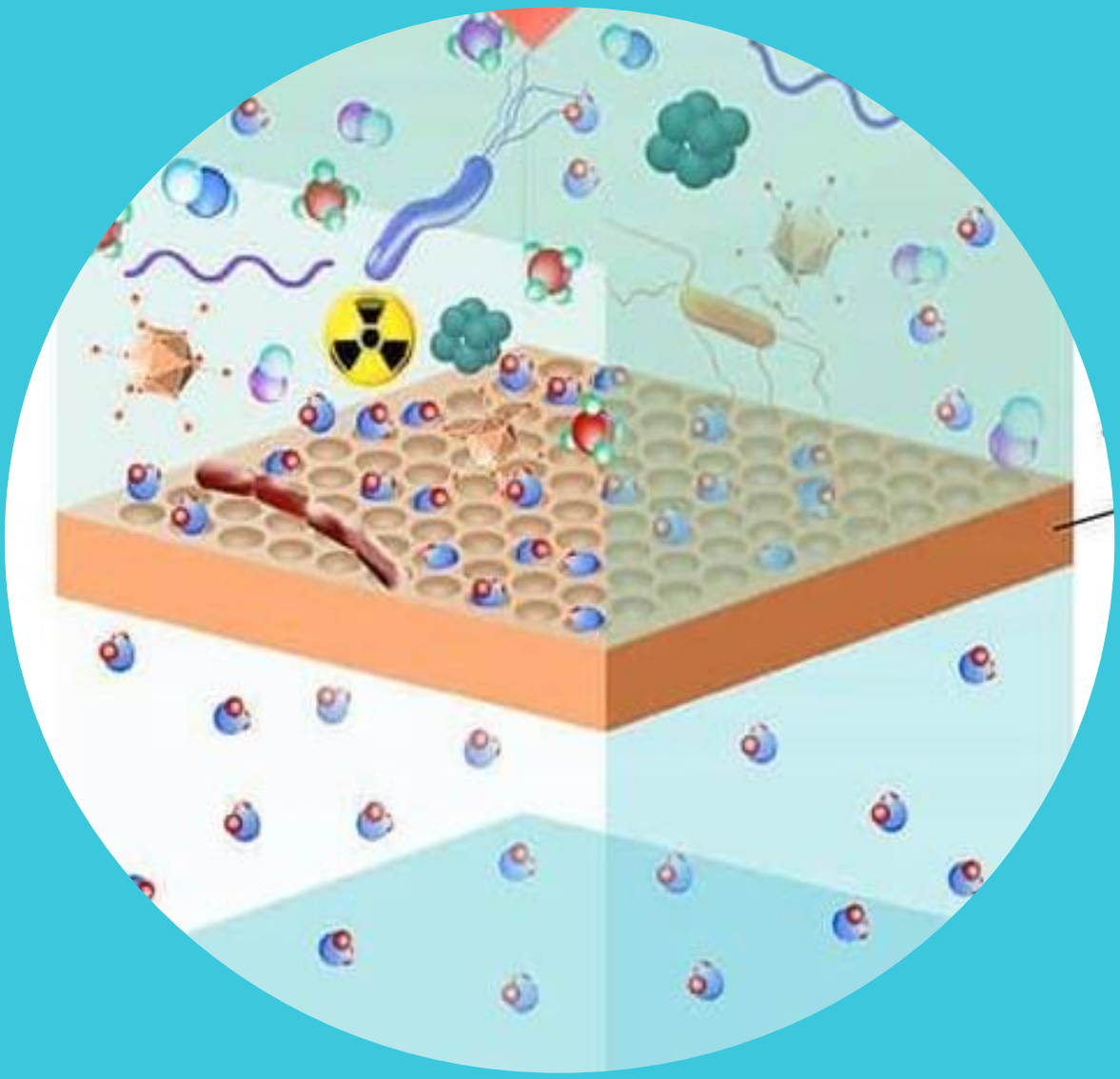


Nanofiltration:
Separating the invisible
Key Stage 4 Programme

Pupil Name	
Handbook Designed by	Reggie Wirawan

Timetable and Assignment Submission

Timetable – Tutorials

1			
2			
3			
4			
5			
6 (Feedback)			

Timetable – Homework Assignments

Tutorial 1		
Tutorial 2		
Tutorial 3		
Tutorial 4		
Tutorial 5		

Assignment Submission – Lateness and Plagiarism

Lateness	
Submission after midnight on 9th August	10 marks deducted
Plagiarism	
Some plagiarism	10 marks deducted
Moderate plagiarism	20 marks deducted
Extreme plagiarism	Automatic fail

The Brilliant Club KS4 Programme – Pupil Feedback Report

Grade	Marks	What this means
1st	70+	Performing to an excellent standard at A-level
2:1	60-69	Performing to a good standard at AS-level
2:2	50-59	Performing to an excellent standard at GCSE
3rd	40-49	Performing to a good standard at GCSE
Working towards a pass	0-39	Performing below a good standard at GCSE
Did not submit	DNS	No assignment received by The Brilliant Club

Lateness	
Any lateness	10 marks deducted
Plagiarism	
Some plagiarism	10 marks deducted
Moderate plagiarism	20 marks deducted
Extreme plagiarism	Automatic fail

Name of PhD Tutor			
Title of Assignment			
Name of Pupil			
Name of School			
ORIGINAL MARK / 100		FINAL MARK / 100	
DEDUCTED MARKS		FINAL GRADE	

If marks have been deducted (e.g. late submission, plagiarism) the PhD tutor should give an explanation in this section:

Learning Feedback Comment 1 -	
Learning Feedback Comment 2 –	
Learning Feedback Comment 3 –	
Resilience Comment	

Contents

Course Rationale 5

Mark Scheme 6

Glossary of Keywords 9

Tutorial 1 10

Tutorial 2 12

Tutorial 3 15

Tutorial 4 17

Tutorial 5 22

Tutorial 6 23

Reflection on feedback 24

Appendices

Referencing correctly 25

Course Rationale

Suppose you've prepared yourself a jug of blackcurrant cordial drink (i.e. you mixed water and blackcurrant cordial) and realised that you don't really like blackcurrant. Instead of pouring it down the drain, you wondered if there's a way to 'undo' it, that is to separate or unmix the cordial and the water? Well, you may be in luck, because with the advances in filtration technology, you just might be able to separate the cordial concentrate from water using membrane filtration.

A common example of this membrane filtration technology is a process called reverse osmosis, which is being employed all around the world to turn untreated/dirty/salty water into clean/drinking water, and there are many more examples. In this course we are going to explore the concept of filtration and more specifically **nanofiltration** (don't worry, you WILL know what it is by the end of the course).

Rationale:
- Filtration is often the most efficient ways of separating components in liquid mixtures or solutions
- Many important real-life applications
- Learning some of the fundamental principles behind nanofiltration

Benefits to pupils:
- They will learn the some of the physical and chemical concepts behind filtration
- They will learn examples on how scientific principles is applied to real-life applications
- They will learn some skills in designing a simple experiment
- They will learn skills in conveying scientific ideas into a poster, including referencing and finding scientific resources

Activities:
- Simple experiment on designing the best filtration systems and qualitatively measuring surface tension of a liquid
- Tutorials on the fundamental concepts of nanofiltration
- Preparing a poster on nanofiltration real-life case study

Mark Scheme Table

	Skills	1st (70-100)	2:1 (60-69)	2:2 (50-59)
Subject knowledge	Knowledge and Understanding	○ All content included is relevant to the general topic and to the specific question ○ Good understanding of all the relevant topics. ○ Scientific terms are defined and used accurately throughout	○ Most of the content included is relevant to the general topic and to the specific question/title ○ Good understanding of most the relevant topics ○ Scientific terms are used accurately but not always clearly defined.	○ Some of the content included is relevant to the general topic and to the specific question/title ○ Good understanding on some of the relevant topics but occasional confusion on others. ○ Scientific terms are used mostly accurately with occasional confusion and often not defined.
Critical thinking	Research and Evidence	○ Use evidence/calculations to support claims, consistently clearly and convincingly ○ Evidence of further reading beyond materials provided which were used in an appropriate context ○ Data is effectively analysed and appropriate assumptions/conclusions are reached	○ Use evidence/calculations to support claims, mostly clearly and convincingly ○ Evidence of further reading beyond materials provided ○ Data is analysed and the assumptions/conclusions that are reached are mostly appropriate	○ Use evidence/calculations to support claims, at times clearly and convincingly ○ Limited evidence of further reading beyond materials provided ○ There is an attempt to analyse data is and draw assumptions/conclusions
	Developing an Argument	○ Argument/proof exceptionally well-developed and well-justified ○ Makes links effectively between subjects that have not previously been associated ○ Uses concepts from the tutorials in an unfamiliar context, and does so accurately and confidently. ○ Content is analysed	○ Argument/proof clear and well-developed and position justified ○ Some evidence of linking subjects that have not previously been associated ○ Use some concepts from the tutorials in an unfamiliar context, but not always accurate ○ Analysis of content to support the argument	○ Argument/proof clear but not well-developed ○ Limited evidence of linking subjects that have not previously been associated ○ Limited use of concepts from the tutorials in other contexts ○ Some analysis of content to support the argument

		effectively to support the argument		
	Critical Evaluation	○ Moved beyond description to an assessment of the value or significance of what is described ○ Effective critiques on the reliability of sources provided	○ Mostly description but some assessment of the value or significance of what is described ○ Some evidence of critiques on the reliability of sources provided	○ Only description with minimal assessment of the value or significance of what is described ○ Limited evidence of critiques on the reliability of sources provided
Written communication	Structure and Presentation	○ Ideas are arranged in a logical structure that is appropriate for the assignment ○ The introduction clearly outlines how the aim of the poster ○ The conclusion summarises all the main points clearly and concisely ○ All calculations, formulas and methods are clearly structured, clear to follow and correct ○ Tables and graphs are effectively constructed including appropriate headings, units and scales. ○ All sources are referenced correctly in an agreed format	○ Ideas are arranged in a structure that is mostly appropriate for the assignment ○ The introduction adequately outlines the aim of the poster ○ The conclusion summarises most of the main points clearly ○ Calculations, formulas and methods are mostly structured, clear to follow and correct ○ Most tables and graphs are well constructed ○ Most sources are referenced correctly in an agreed format	○ Ideas are arranged in a structure ○ The introduction mentions how the aim of the poster ○ The conclusion summarises some of the main points clearly ○ Calculations, formulas and methods are not always structured, clear to follow and correct. ○ Some tables and graphs are well constructed but contains some errors ○ Some sources are referenced correctly in the agreed format with occasional errors

	Language and Style	○ No spelling, grammar or punctuation errors ○ Units and significant figures are presented accurately throughout ○ Writing style consistently clear, appropriate for scientific documents and easy to follow ○ Accurate and consistent use of technical language and vocabulary	○ Minimal spelling, grammar or punctuation errors ○ Units and significant figures are presented accurately throughout ○ Writing style mostly clear, appropriate for scientific documents and easy to follow ○ Some attempts of using technical language and vocabulary, but not always accurate	○ Some spelling, grammar or punctuation errors ○ Units and significant figures are presented accurately throughout with occasional errors ○ Writing style moderately clear, appropriate for scientific documents and easy to follow ○ Use of simple language and vocabulary effectively but struggles to use technical language

Glossary of Keywords

(fill it up as you go along, one has been done for you)

Word	Definition	Example/further notes/equation
Membrane (in filtration process)	A thin layer material that allows certain compounds to get through but not others.	'Semi-permeable'

Tutorial 1 – Membrane Filtration Technology

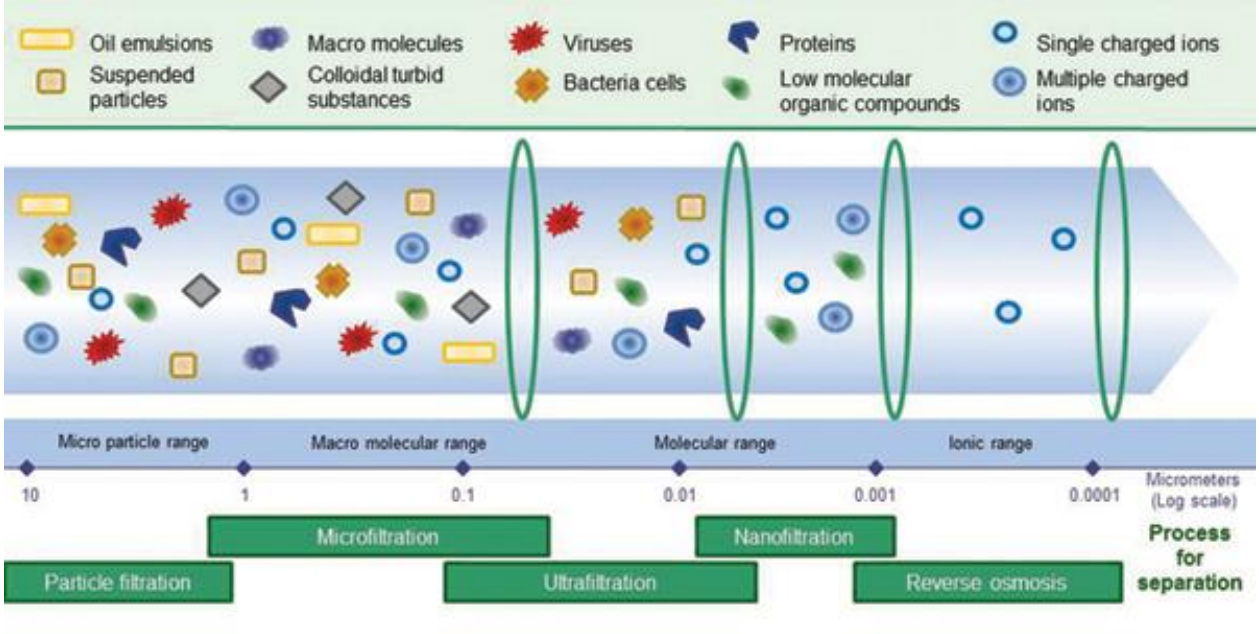


Figure 1. Illustration for membrane separation processes

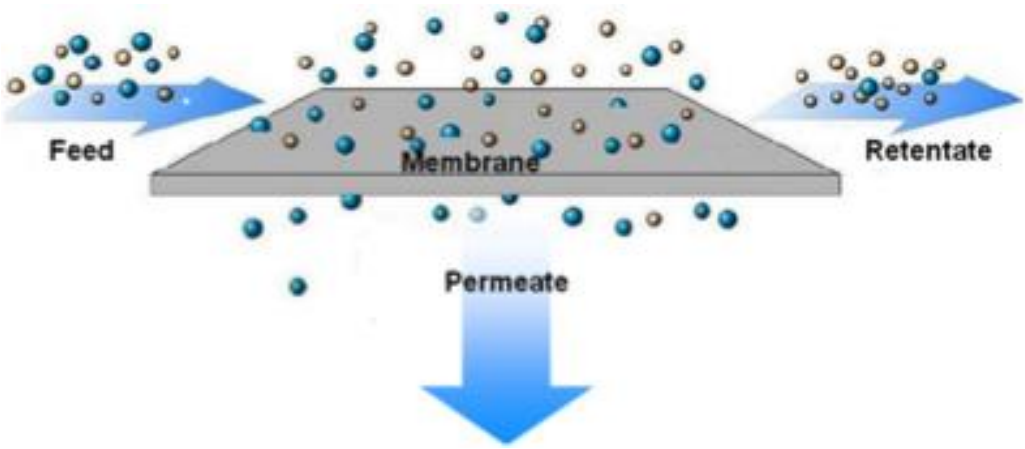
What is the Purpose of Tutorial 1?

- To understand the concepts about membrane filtration
- Practical/demonstration activity: designing the best filtration system from everyday objects
- To cement the understanding of the following terms/concepts:
  - atom, molecule, element, compound
  - mixture, suspension, solution, solvent, solute, dissolve

Homework 1:

Based on the filtration practical demonstration we've done and explanation given around it, answer the below questions.

1. Name the process illustrated by the below diagram and describe it in your own words. Explain what the blue and yellow spheres represent.



2. Contrast (explain the difference) between these pair of keywords, and give two examples for each term:

Solute vs. solvent

Suspension vs. solution

3. Explain the following terms and use it in a sentence or give an example:

Membrane filtration

Nanofiltration

4. Membrane is semi-permeable, i.e. letting through (permeating) certain molecules but rejecting others. Why is this so? How (by what mechanisms) can a membrane reject only certain molecules?

Tutorial 2 – Process Flow Diagram & Basic Calculations

Figure 2. A reverse osmosis unit

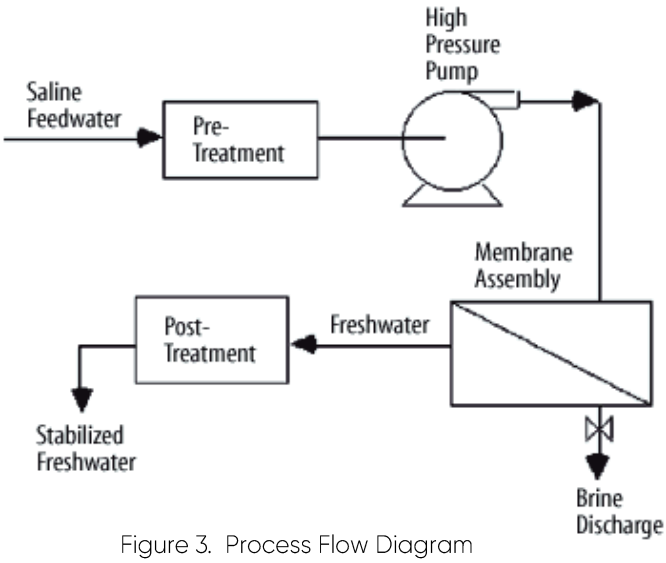


Figure 3. Process Flow Diagram

What is the Purpose of Tutorial 2?

- To understand what is a Process Flow Diagram (PFD) and be able to draw a simple PFD
- To understand the concept of the following terms surrounding membrane separation processes: flux, rejection, trans-membrane pressure, permeate, retentate, molecular weight (MW) or molecular mass
- To be able to carry out calculations of some basic equations of membrane process

Process Flow Diagram (PFD)

Consider the picture of a reverse osmosis (RO) unit (Figure 1) and its process flow diagram (PFD) (Figure 2). PFD is a diagram commonly used in chemical and process engineering to indicate the general flow of plant processes and equipment. The PFD displays the relationship between major equipment of a plant facility and does not show minor details such as piping details and designations.

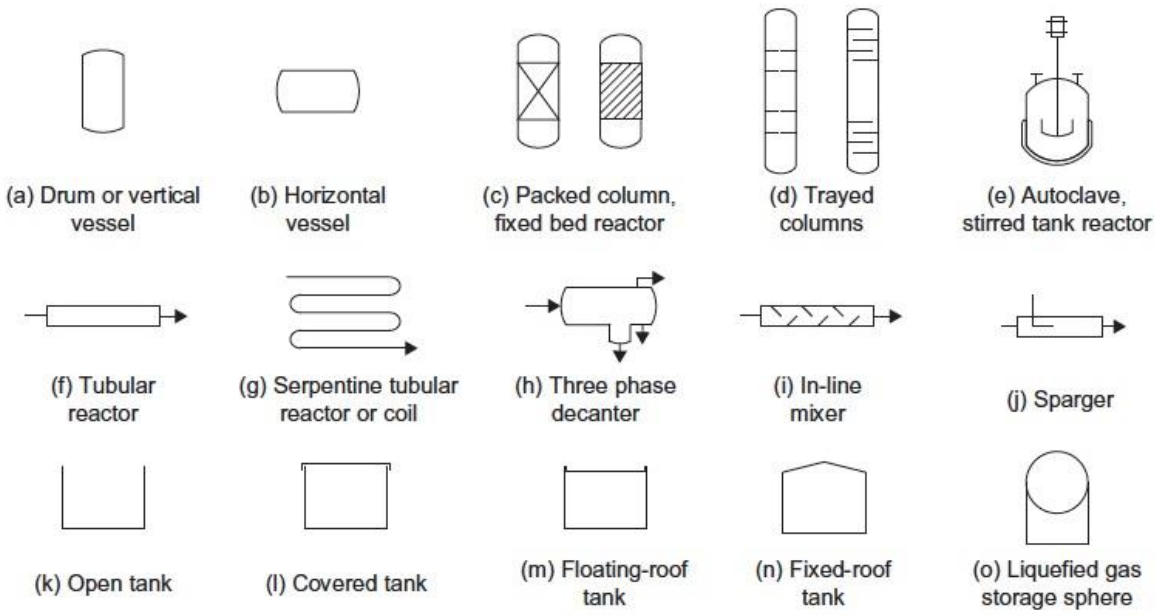


Figure 4. Some of the PFD symbols used in process engineering. On this course, however, you will only be required to draw PFD using only several basic symbols.

Membrane Filtration Fundamentals

(take notes as we go along Tutorial 2)

Flow rate

Flux

Rejection

Volume Concentration Factor (VCF)

Molecular Weight (Mw)

Homework 2

1. A feed solution of 200,000 gal/d are flowing through a membrane with an area of 4,000 ft^2.
   a. What is the flux of this process?

   b. What is the flux in $L/(hr.m^2)$? (1 US gal = 3.785 L and 1 ft^2 = 0.0929 m^2)

2. Dissolved gases like ammonia (NH_3) will not be rejected by RO membrane; however, NH_3 is in equilibrium with the ammonium cation (NH_4^+), as defined by the following equation:

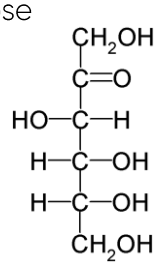
   $$NH_3 + H^+ \text{<---> } NH_4^+$$

   Decreasing the pH and/or temperature will convert NH_3 to NH_4^+, which is rejected by RO membrane. As long as the temperature and pH are less than 40°C and 7 respectively, more than 95% will be present as $NH4^+$ and the rejection should be better than 98%. If the NH_3 concentration in the feed is 0.2 mg/L, what is its concentration in the treated water?

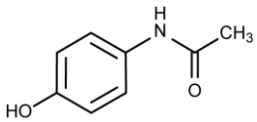
3. Calculate the molecular weight of the following compounds (you will need Periodic Table). Show your working.

   Ammonia (NH_3)

   Fructose

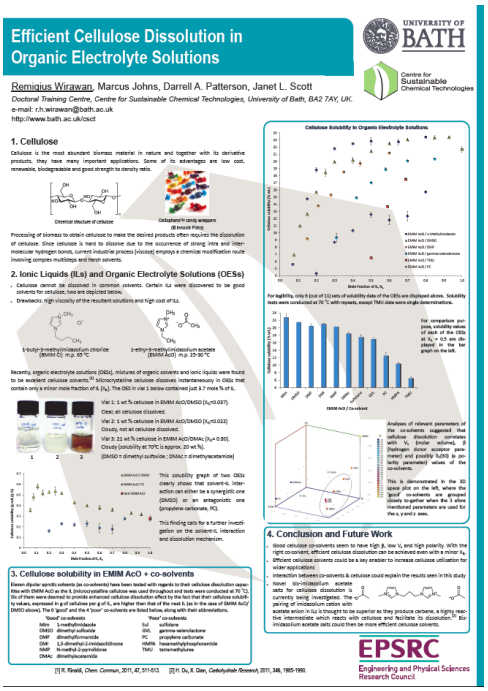
   

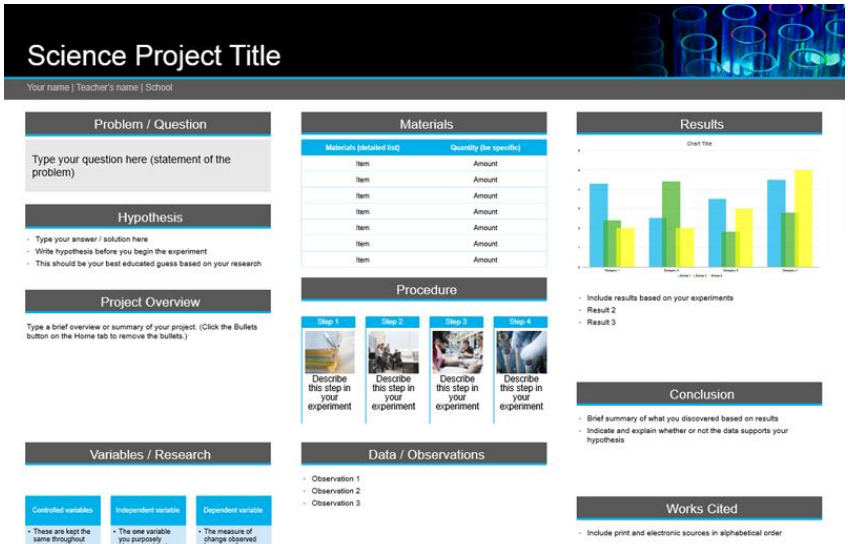
   Paracetamol ($C_8H_9NO_2$)

4. Find an example of a scientific poster (can be your own or from internet) to bring it to Tutorial 3. If you look for one from the internet, ensure that it is at the appropriate level (i.e. GCSE/high school level) and that it is legible (a softcopy, i.e. Word/pdf file, would be great).

Tutorial 3 – Preparing a scientific poster





What is the Purpose of Tutorial 3?

- You will learn the skillsets required to prepare a scientific poster: graphing, referencing, and finding scientific resources.

Scientific Poster

We will review some of the scientific posters that we have and critically discussing. Answer the questions below as we go along.

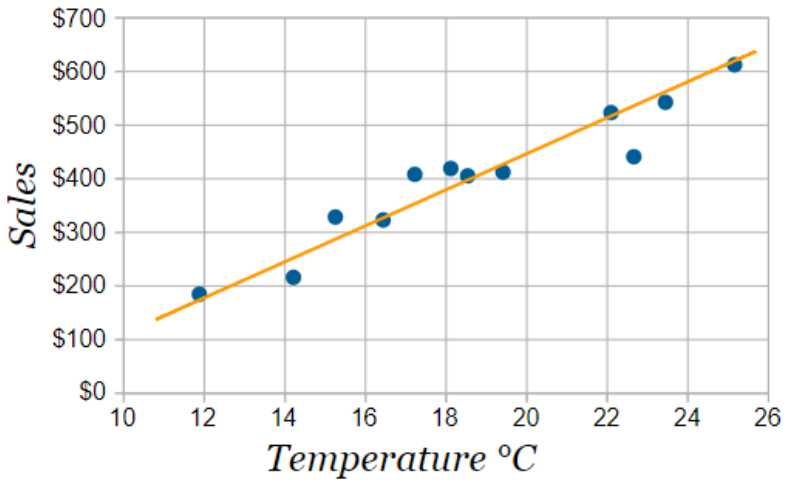
What could be the aim(s) of a scientific poster?

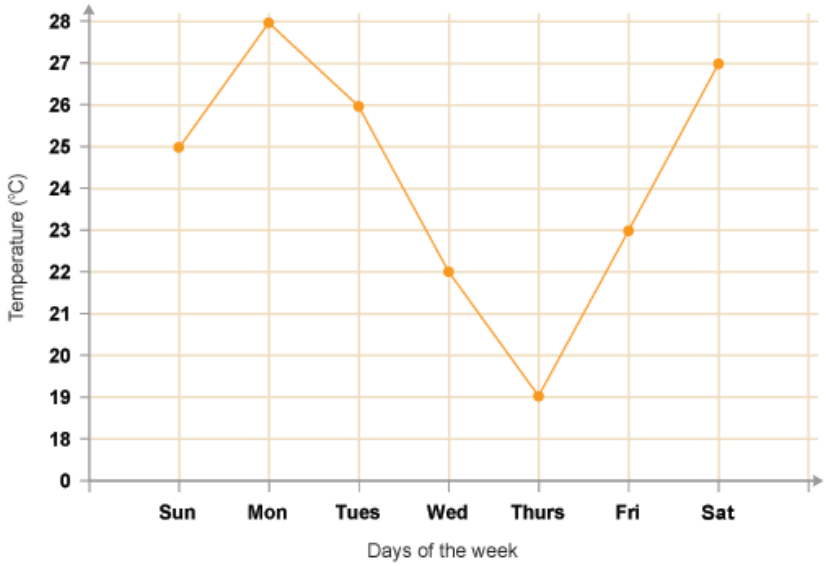
What is the structure (think in terms of headings) of a scientific poster?

What makes a good scientific poster?

Homework 3

1. Using the correct graph type to represent a set of data is important. Take a look at the 2 graphs below, one is a line graph and the other is a scatter graph. Which one is which and what is the fundamental difference?





2. Using a software package of your choice (I recommend PowerPoint but others could work), have a go in designing a template for your scientific poster. You can look for prepared template in the internet and modify it to your liking.

Extension/optional

3. Below is a set of data of the number of visitors visiting a museum over a 10 day period with the daily sunshine totals. Using Excel or other spreadsheet software, create a scatter graph for this.

Hours Sunshine	6	0.5	8	3	8	10	7	5	3	2
Visitors	300	475	100	390	200	50	175	220	350	320

Tutorial 4 – Final Assignment: Nanofiltration Case Study Poster

Figure 5. A pilot plant for concentrating milk by means of membrane technology (from https://phys.org/news/2014-10-milkhow-energy.html)

What is the Purpose of Tutorial 4?

- You will be introduced to your final assignment. You will each have an individualised, real-life nanofiltration case study, for which you will have to prepare a poster of.
- You will explore several PowerPoint poster templates and other alternative tools/formats to prepare your poster.

Final Assignment

Each of you will be assigned a real life nanofiltration case study where you will have to present it in a poster. You need to have the following elements in your poster:

1. Simple, but labelled process flow diagram.
2. Three or four figures, with graph or table make up two of the figures.
3. The answer or solution to the accompanied questions that come with each case study.

Case Study A. Concentration of Lactose

Nanofiltration (NF) technology is commonly used after ultrafiltration (UF) to further concentrate acid whey UF permeate for whey processing applications within the dairy industry. The removal of salts via NF is important for the production of high-quality lactose, and can also prevent scaling and build-up on evaporators. In this case study, two of NF membranes (NFS and NFX) were tested for their lactose concentration and demineralisation capabilities, with specific focus on calcium removal. Some of the membrane performance and operating data are provided below. The feed stream will be the acid whey UF permeate. These results will determine the potential for NFS to be used in the dairy industry for applications such as lactose concentration and demineralization,

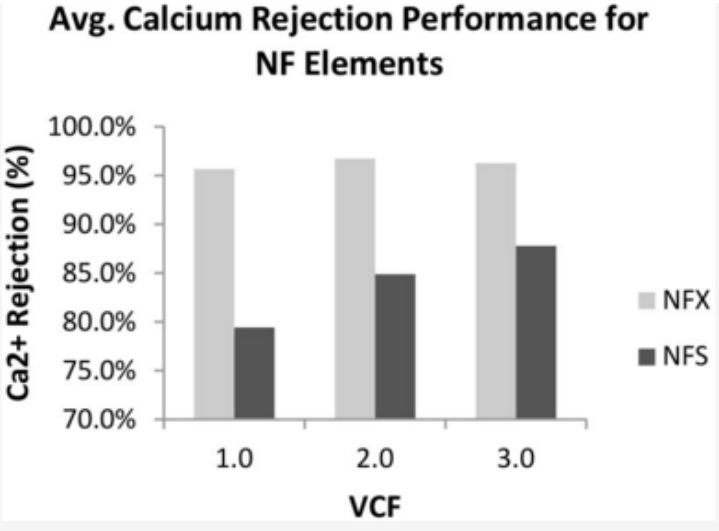


Figure 1. Average calcium rejection performance for NFX and NFS membranes.

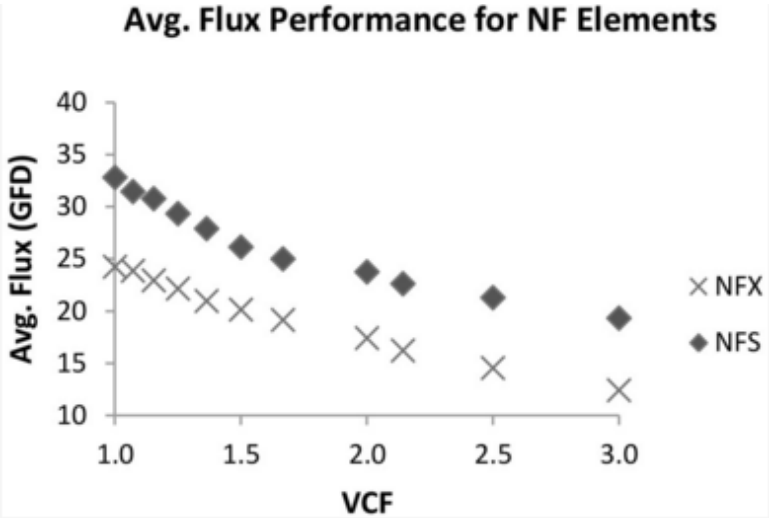


Figure 2. Average flux performance for NFX and NFS membranes. Note: GFD is gal/day/ft^2

Membranes were tested at 440 psi with a feed flow rate of 2 gpm at 25°C. The concentration of Ca^{2+} in the feed stream is 2.5 wt.%. Permeate flux and calcium rejection was measured from 1x to 3x volumetric concentration factor (VCF).

Include the answers/solutions to these questions in your poster:

- What is the quantity of each membrane would you need to achieve a product flow rate of 75 gal/day?

- What is the calcium concentration in the permeate stream for each of the membrane?
- Which membrane would you recommend for this application? Why? Describe advantages/disadvantages for each.

Case Study B. Amoxicillin Removal

The rise in antibiotic consumption lends forth the need for new technology to remove it from wastewater and prevent further contamination in aquatic environments. The presence of antibiotics in aquatic environments is leading to adverse health effects for both animals and humans, and the removal of antibiotics is important for the reuse of wastewater. Certain strains of disease-causing bacteria are also beginning to develop resistance large doses of antibiotics. Given that the size of most antibiotics falls within the range of 200 to 1,200 Daltons, nanofiltration (NF) membranes have the potential to be widely successful for antibiotics removal in wastewater treatment.

NFS and NFX flat sheet membranes were tested at amoxicillin concentrations ranging from 100ppm to 500ppm. The membranes were tested at 120psi with a feed flow rate of 0.5gpm at 25°C. Permeate flux and TOC rejection were measured for all samples. NFS exhibited a 21-24% increase in flux over NFX throughout the duration of the test. This membrane also performed slightly higher than NFX in terms of amoxicillin rejection at all concentrations. Figure 1 shows the flux and rejection performance from 100 to 500 ppm for both membrane types.

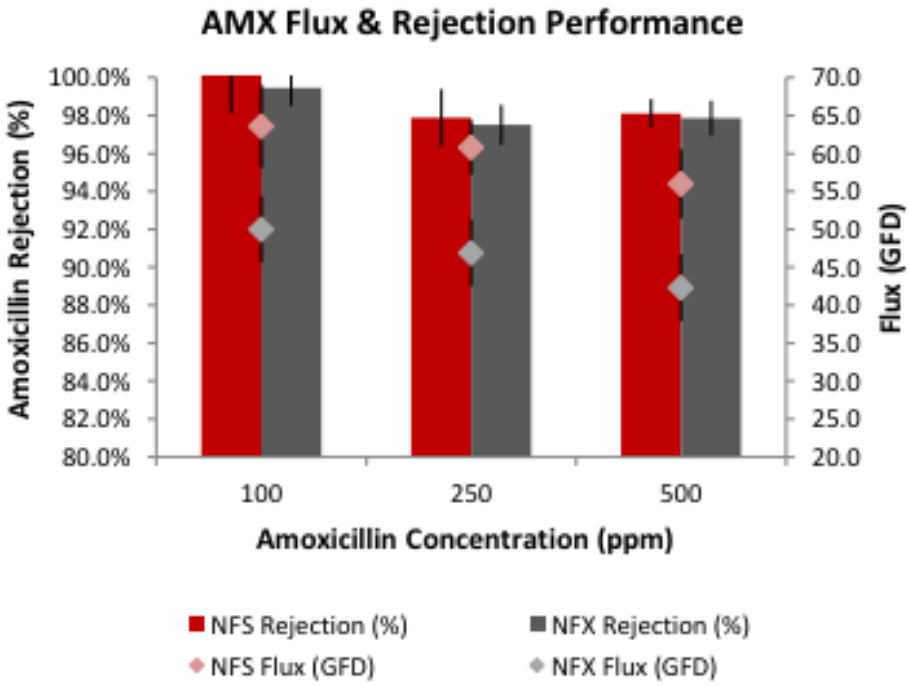


Figure 1. Flux and rejection performance from 100 to 500ppm for both membrane types

Include the answers/solutions to these questions in your poster:

- What is the quantity of each membrane would you need to achieve a product flow rate of 75 gal/day?
- What is the amoxicillin concentration in the permeate stream for each of the membrane?
- Which membrane would you recommend for this application? Why? Describe advantages/disadvantages for each.

Case Study C. Demineralisation of Lactose

In the concentration of whey protein, the by-product generated is a salty lactose solution. This lactose can be concentrated with a nanofiltration membrane for use in the food, pharmaceutical, and brewing industries. Two different NF membranes, the NFX (150-300Da) and the NFW (300-600Da), which were both tested for effectiveness in concentrating and desalting a simulated lactose feed stream.

Test 1: NFX
Feed Solution, Membrane, and Operating Conditions

Feed Solution	
Material	Simulated Sweet Whey UF Permeate
Lactose Concentration	4%
Salt Concentration (NaCl)	0.5%
Synder Membrane	
Element	NFX-Spiral Element
Membrane	Polyamide-TFC
NF Standard Operating Parameters	
Pressure (PSI)	110
Temperature (C)	20-25

Results
The NFX's performance in separating lactose and salt is summarised on the table below.

Filtration Results	
Lactose Concentration Factor	3-4
Lactose Concentration in Resulting Feed	14%
Average Permeate Flux (GFD)	21
Overall Lactose Rejection (%)	>98.5

Test 2: NFW
NFW membrane was also tested in a constant volume diafiltration mode where DI water was added to the feed stream with an equal amount of permeate water extracted from the demineralization process. The operating conditions are the same as Test 1 above. The feed solution contains 8% lactose and 0.44% sodium chloride.

Filtration Results	
Total Volume of DI Water Used (Gal)	>18
Salt Dilution Factor	5.7
Salt Concentration in Final Feed (ppm)	770
Average Permeate Flux (GFD)	11.6
Overall Lactose Rejection (%)	>94%

Include the answers/solutions to these questions in your poster:

- What is the quantity of each membrane would you need to achieve a product flow rate of 75 gal/day?
- What is the salt rejection (%) in Test 2? Which stream is the desired product?
- Which membrane would you recommend for this application? Why? Describe advantages/disadvantages for each.

Case Study D. Natural Dissolved Organic Matter (DOM) Recovery

Surface water may have high levels of dissolved organic matters (DOM) in many parts of the world. In many cases, DOM must be removed via chemical flocculation and/or coagulation from water before use. With the help of nanofiltration technology, DOM can also be separated and purified into a natural additive for fertilizers to improve the structure of soil and enhance the nutrient acceptance level by a wide variety of plants. In this specific case, a customer was seeking an energy-saving technology to concentrate the DOM from a swamp in Georgia. Obviously, the more concentrated the humic acid is in the final product, the higher the value and the greater the savings in transport costs. NFX membrane was tested in a two month field trial and resulted in a concentration factor of up to 100x, making NF technology a viable solution to achieve the concentration goal.

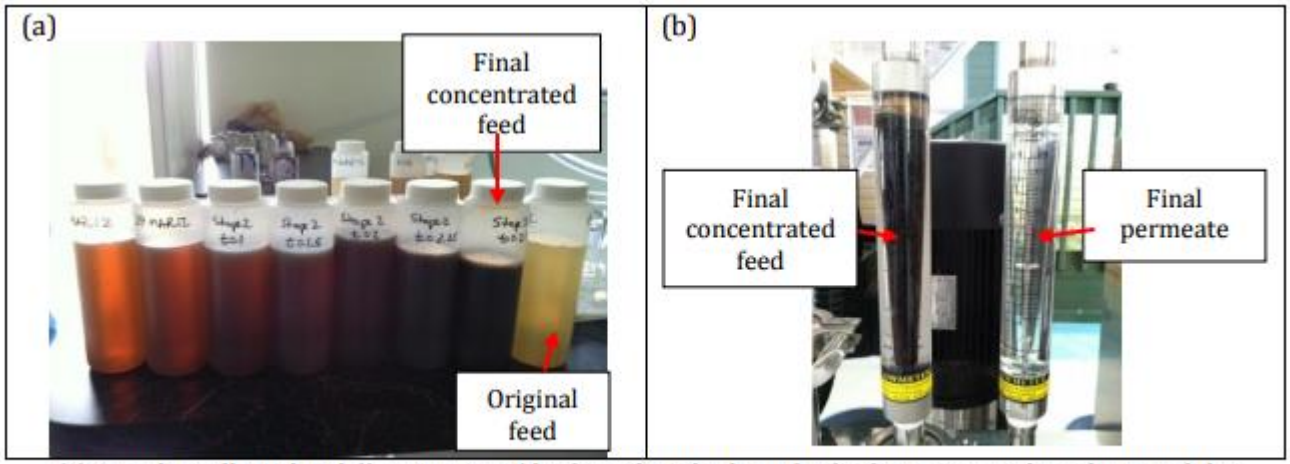
Membrane and Testing Conditions

Feed Conditions (River)	
Conductivity (us/cm)	85
pH	~6
Absorption w/o pH adjustment	0.516
Turbidity	2.82
Beginning volume (gal)	600
Synder Membrane	
Element	NFX-2-2540 HM Spiral Element
Membrane	Polyamide-TFC
NF Standard Operating Parameters	
Crossflow (gpm)	5 gpm
Operating pressure (psi)	210 psi
Pressure drop (psi)	5 psi
Wavelength with UV-Vis	420 nm

Results:
The NFX permeate was plotted over the course of concentration from concentration factor of 1 to 125. The initial permeate flux was at 55 gfd, and the permeate flux at a concentrate factor of 116 was 15 gfd. The overall flux declined 70%, but the flux was highly recoverable via cleaning with acid cleaner and alkaline detergent.

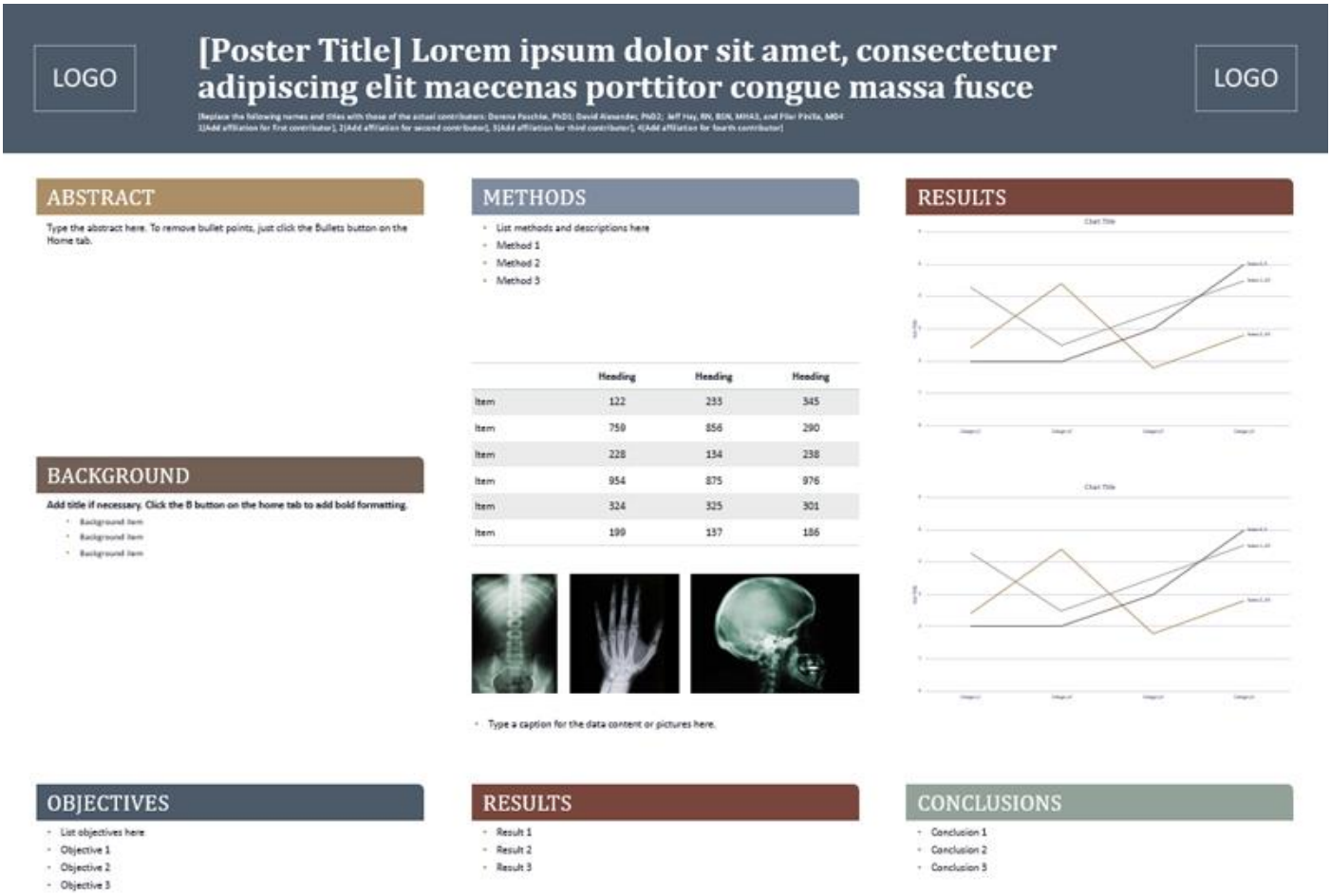
The pictures (a) and (b) show that NFX membrane can concentrate the materials progressively and the permeate appears to be clean even when the product was highly concentrated by more than 100 fold.

Include the answers/solutions to these questions in your poster:
1. What is the quantity of membrane needed to achieve a product flow rate of 75 gal/day?
2. What is the conventional process for recovery of DOM/humic acid?
3. Describe advantages/disadvantages for each this membrane technology and the conventional process mentioned above.



(a) Samples collected at different stages (the far right side show the final concentrated products and the original feed solution); and (b) the concentrate and permeate flow meters at the end of a 100-fold concentration.

Tutorial 5 – Support Session for Final Assignment



What is the Purpose of Tutorial 5?

- You will get guidance for your individualised final assignment and you will have opportunity to work on it and ask questions.

Some advice/hints/tips on completing this assignment:

1. Don't be put off if all seems a bit overwhelming or difficult. I can assure you that you have all the tools and knowledge to complete the assignment. Be clear in your head what are being asked to produce and work on one task at a time.
2. Some of the information/data given are relevant, some are not, and some are missing. Use the relevant ones, ignore the irrelevant ones and research/ask for the missing pieces that you need. This is what engineers do when solving problems in real life.
3. Tutorial 5 will be dedicated to support you towards completing your poster, but for the session to be useful, you have to come with questions and having already worked through some of the problems in your case study.
4. When you seem stuck not having an important piece of information to solve a problem, don't give up, instead, make a best guess/estimate/assumption to enable you to work through a problem, but make sure you state what those are. This is a valid approach in engineering world. Often near enough answer is good enough.
5. Remember that you don't have to have intimate understanding on every single aspect of your case study to be able to complete the assignment.

Tutorial 6 – Feedback tutorial

What is the Purpose of Tutorial 6?

- To receive feedback on final assignments.
- To share examples of best practice with the other pupils in your group.
- To write targets for improvement in school lessons.
- To reflect on the programme including what was enjoyed and what was challenging.

Final assignment feedback

What I did well…	What I could have improved on…
•	•
•	•
•	•

My target for future work is…

Reflecting on Uni Pathways

What did you most enjoy about Uni Pathways?
• • •

What did you find challenging about the programme?	How did you overcome these challenges?
• • •	• • •

Appendix 1 – Referencing correctly

When you get to university, you will need to include references in the assignments that you write, so we would like you to start getting into the habit of referencing in your Brilliant Club assignment. This is really important, because it will help you to avoid plagiarism. Plagiarism is when you take someone else's work or ideas and pass them off as your own. Whether plagiarism is deliberate or accidental, the consequences can be severe. In order to avoid losing marks in your final assignment, or even failing, you must be careful to reference your sources correctly.

What is a reference?

A reference is just a note in your assignment which says if you have referred to or been influenced by another source such as book, website or article. For example, if you use the internet to research a particular subject, and you want to include a specific piece of information from this website, you will need to reference it.

Why should I reference?

Referencing is important in your work for the following reasons:

- It gives credit to the authors of any sources you have referred to or been influenced by.
- It supports the arguments you make in your assignments.
- It demonstrates the variety of sources you have used.
- It helps to prevent you losing marks, or failing, due to plagiarism.

When should I use a reference?

You should use a reference when you:

- Quote directly from another source.
- Summarise or rephrase another piece of work.
- Include a specific statistic or fact from a source.

How do I reference?

There are a number of different ways of referencing, and these often vary depending on what subject you are studying. The most important to thing is to be consistent. This means that you need to stick to the same system throughout your whole assignment. Here is a basic system of referencing that you can use, which consists of the following two parts:

1. A marker in your assignment: After you have used a reference in your assignment (you have read something and included it in your work as a quote, or re-written it your own words) you should mark this is in your text with a number, e.g. [1]. The next time you use a reference you should use the next number, e.g. [2].
2. Bibliography: This is just a list of the references you have used in your assignment. In the bibliography, you list your references by the numbers you have used, and include as much information as you have about the reference. The list below gives what should be included for different sources.

    a. Websites – Author (if possible), title of the web page, website address, [date you accessed it, in square brackets].

    E.g. Dan Snow, 'How did so many soldiers survive the trenches?', http://www.bbc.co.uk/guides/z3kgjxs#zg2dtfr [11 July 2014].

    b. Books – Author, date published, title of book (in italics), pages where the information came from.

    E.g. S. Dubner and S. Levitt, (2006) *Freakonomics*, 7-9.

    c. Articles – Author, 'title of the article' (with quotation marks), *where the article comes from* (newspaper, journal etc.), date of the article.

    E.g. Maev Kennedy, 'The lights to go out across the UK to mark First World War's centenary', Guardian, 10 July 2014.

Notes

Notes

UNI PATHWAYS

UNI PATHWAYS