Decisions Behind The Closed Door of Aircrafts: An Experimental Design Approach

Key Stage 4 Programme

Pupil Name	
Handbook Designed by	Dr George

Timetable and Assignment Submission

Timetable – Tutorials

Tutorial	Date	Time	Location
1			
2			
3			
4			
5			
6 (Feedback)			

Timetable – Homework Assignments

Homework Assignment	Description	Due Date
Tutorial 1	Base line Test	
Tutorial 2		
Tutorial 3		
Tutorial 4		
Tutorial 5		

Assignment Submission – Lateness and Plagiarism

Lateness	
Submission after midnight on 19 July	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

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Course Rationale

Much of the advancements in the fields of science and engineering comes from performing experiments. In the engineering sector, design of experiment can be used to systematically investigate interactions between the elements in a design and how these interactions affect the variation in the output measure. After the process conditions and parameters that influence the quality of the product, you can direct improvement efforts to enhance a product's manufacturability, reliability, quality and field of performance. Planning an experiment effectively and precisely is essential in order to ensure that appropriate types of data and sufficient design settings are available in order to examine the research hypotheses.

Experimental design is a cost-effective approach to practical experimentation that allows the effect of variables to be assessed using only the minimum of resources. A proper experimental design serves as a road map to the study methods, thus helping students to understand more clearly how data were obtained and, therefore, assisting them in properly analysing the results and implementing it. Examples will be used throughout this course to illustrate various aspect of the experimental design modelling process.

This course utilises hands-on activities to help students learn the criteria for experimental design and how to select the appropriate designed experiment type to run. The course offers practical, immediate and critical skills in the complete cycle of brainstorming, designing, implementing and running controlled experiments. Students will experience setting up, running, and analysing the results of full or fractional factorial designs that facilitates good experimental designs and data analysis. They will use their knowledge of design of experiment "to find the optimal design settings of the design parameters to maximise the time of flight of a paper helicopter." This course will benefit a vast range of students with interest in science, engineering, research and manufacturing and statistics. Typical applications include product development, process improvement/efficiency, optimisation, validation and quality control of products or process chains.

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/title • Good understanding of all the relevant topics. • Scientific terms are defined and used accurately throughout • Clear justification on how the content included is related to the specific issues that are the focus of the assignment	• 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. • Adequate justification on how the content included is related to the specific issues that are the focus of the assignment	• 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. • Some justification on how the content included is related to the specific issues that are the focus of the assignment
Critical Thinking	Research and Evidence	• Inclusion of rich sources of research findings, data, quotations or other sourced material as evidence for the claims/ ideas • Use evidence/ calculations to support claims/assertions/ ideas, 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	• Inclusion of adequate sources of research findings, data, quotations or other sourced material as evidence for the claims/ ideas • Use evidence/calculations to support claims/assertions/ideas, mostly clearly and convincingly • Evidence of further reading beyond materials provided • Data is analysed and the assumptions/conclusions that are reached are mostly appropriate	• Inclusion of some sources of research findings, data, quotations or other sourced material as evidence for the claims/ ideas • Use evidence/ calculations to support claims/assertions/ ideas, 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

Critical Thinking	Developing an Argument	• A point of view or position in relation to the title or question is consistently clear • Argument/proof exceptionally well-developed and well-justified • A position is clearly established in relation to the key research findings, and is developed effectively and consistently throughout the report • 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.	• A point of view or position in relation to the title or question is adequately clear • Argument/proof clear and well-developed and position justified • A position is established in relation to key research finding, and is well-developed in most of the report • 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	• A point of view or position in relation to the title or question is somewhat clear • Argument/proof clear but not well-developed • A position is established in relation to key research findings, and is well-developed in parts of the report • Limited evidence of linking subjects that have not previously been associated • Limited use of concepts from the tutorials in other contexts
	Critical Evaluation	• Moved beyond description to an explanation of the science underlying experimental results. • Evaluative points are consistently explicit/ systematic/reasoned/ justified • Suggest further trials to optimise the design of helicopters	• Mostly description but some explanation of the science underlying experimental results. • Evaluative points are mostly explicit/ systematic/reasoned/ justified • Limited suggestion of further trials to optimise the design of helicopters	• Only description with minimal explanation of the science underlying experimental results. • Evaluative points are at times explicit/ systematic/reasoned/ justified • No suggestion of further trials to optimise the design of helicopters

Written Communication	Structure and Presentation	• Ideas are presented in paragraphs and arranged in a logical structure that is appropriate for the assignment • The introduction clearly outlines how the essay/ report will deal with the issues • 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 presented in paragraphs and arranged in a structure that is mostly appropriate for the assignment • The introduction adequately describes how the essay/report will deal with the issues • 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 presented in paragraphs and arranged in a structure • The introduction mentions how the essay/report will deal with the issues • 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

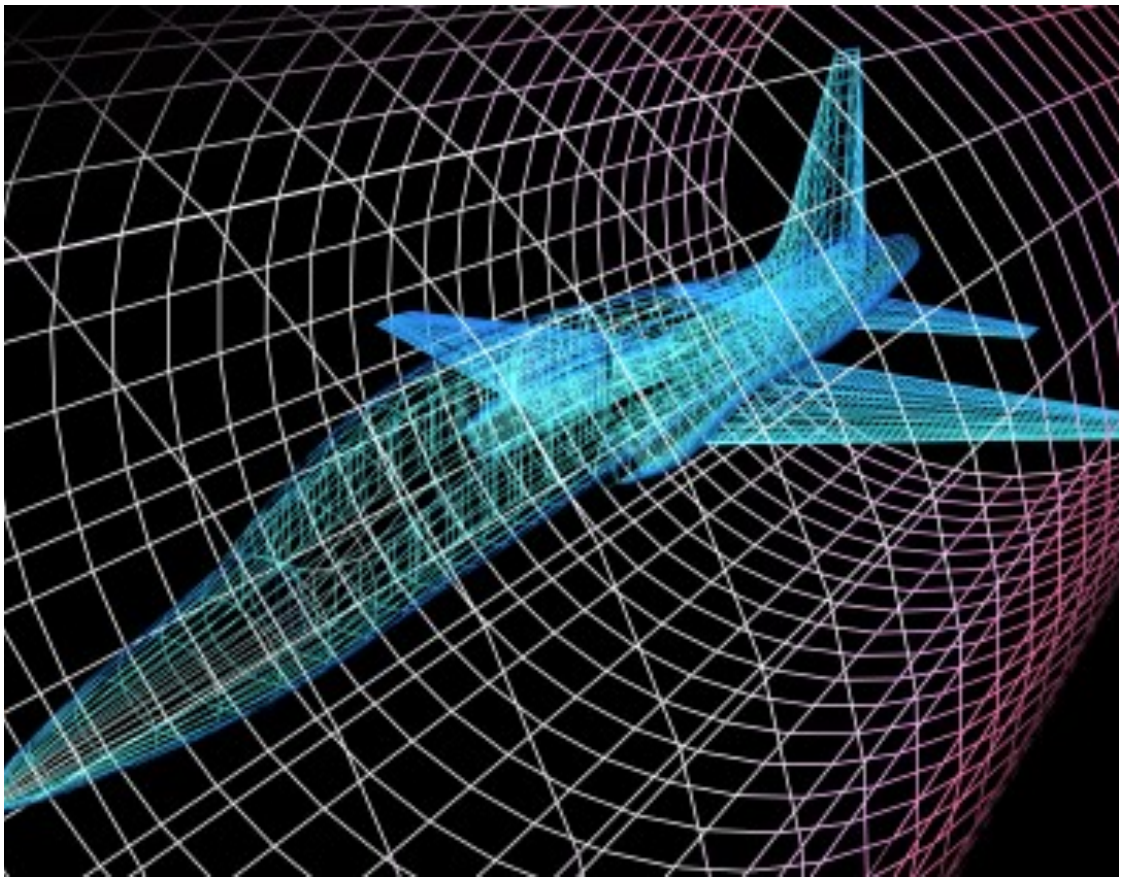
Glossary of Keywords

Word	Definition	In a sentence
Force		
Density		
Acceleration due to gravity		
Thrust		
Lift		
Pressure		
Aerodynamics		
Fluid resistance		
Precision		
Accuracy		

Glossary of Keywords

Word	Definition	In a sentence

Tutorial 1 – From Mathematics and Science to Aircraft Designs



What is the Purpose of Tutorial 1?

- To introduce and outline the aims of the course.
- To understand how physics and mathematics can be applied to engineering designs.
- To explore how the shapes of objects affect flight pattern and predict flight pattern of different objects.

Match up each word to its description

Force	A force that opposes motion between two surfaces in contact.
Acceleration due to gravity	The downward force on an object due to gravity.
Frictional force	A push or pull on an object.
Upthrust (buoyancy)	The acceleration with which bodies fall freely towards the earth.
Weight	The upward force on an object in a fluid (liquid or gas).

State Newton's 3rd law of motion. Give its mathematical expression.

We use forces all the time, often without even noticing. What force are you using now?

A spaceship weighs 10800 N on a planet where the acceleration due to gravity $g = 7.20\ m/s^2$. What would it weigh on another planet where $g = 4.30\ m/s^2$?

An aircraft of weight 1.8×10^6 N flies at a constant height, The pressure difference between the top and bottom of the wings is 1.5×10^4 Pa. Assuming that the lift is produced only by the wings, calculate the effective areas of the wings.

Tutorial 1— Baseline Test

1) Changeable elements of an experiment which can affect the outcome of the experiment if not carefully controlled is called

a. Placebo

b. Variables

c. Quantitative elements

d. Control groups

2) While performing an experiment, it is essential to _____

a. Reach a conclusion

b. Change the control factors

c. Test many several different variables at the same time

d. Record observations and measurements

3) Which of the following is NOT an example of quantitative data?

a. Size of a flower

b. Height of a flower

c. Colour of a flower

d. Number of flowers on a type of plant

4) Which of the following phrases describes an hypothesis?

a. Performing a controlled experiment

b. Reviewing information related to the problem

c. Testing a variable in an experiment

d. Suggesting a solution to a problem after researching it carefully

5) The _____ variable is the variable you are observing and it usually changes in response to the _____ variable

a. Independent, dependent

b. Independent, control

c. Dependent, control

d. Dependent, independent

Write down key words or phrases you want to look up in the dictionary and add these to the glossary of key words in pages 9 and 10 before attempting the next sets of questions

_____

_____

6) Describe the meaning of parameter in your own word

_____

_____

_____

7) Complete the following table for five parameters A—E following the example given in Table below.

A	B	C	C	E
-1	-1	-1	-1	-1
-1		-1		1
-1		-1		
-1		-1		
-1		1		
-1				
-1				
-1	-1			
-1	1			
-1				
-1				
-1				
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-1	1			
1	-1			
1				
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1				
1				
1				
1				
1				
1	1			
1				
1				
1			1	-1
1			1	1

Tutorial 2– Principles of Aerodynamics

What is the Purpose of Tutorial 2?

- To understand the concepts of aerodynamics.
- To learn how air resistance, mass and lift interact
- To learn the basic theory of flight.
- To understand the role of biomimetic in engineering designs.

Video — Man Riding Horizontal Fast

In your own words, describe what happened in the video above.

Using concept mapping, show the link between the video and the concepts of aerodynamics

Discuss the similarities and differences between these figures.

Videos— Ideas Worth Spreading: How A Fly Flies and How insects Flies

What does it take to fly?

_____

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How do insects flies? Describe how the insect wings generate enough force to fly in the air.

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Compare and contrast flies/insects to aircrafts

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What keeps aircrafts in the air as it flies?

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Describe friction and what causes it?

Draw a free-body diagram of the forces acting on a moving object. In which direction does the force of friction act?

Describe fluid resistance (or drag)?

Try a quick experiment. Hold a strip of paper just below your lips and blow across its top surface. Discuss what you expected and what happened?

An aeroplane's wings have a total surface area of 480 m^2. The pressure difference between the upper and lower surfaces of each wing is 6500 Pa. Calculate the lift created.

Tutorial 2 — Homework

Watch the videos Hummingbird and Aerodynamics, The click mechanism in insect flight, and Dragonfly Wings in Slow Motion.

Describe the mechanism of flight of the hummingbird and the dragonfly.

What does the video show you about the principle of flight?

Use the internet to find three interesting facts about the flight mechanism and flight pattern of a dragonfly. Write down the names and URL (web address) of each website you used in your research. Try to use different websites.

Fact 1

_____

_____

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Website name:

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Website URL:

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Fact 2

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Website name:

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Website URL:

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Fact 3

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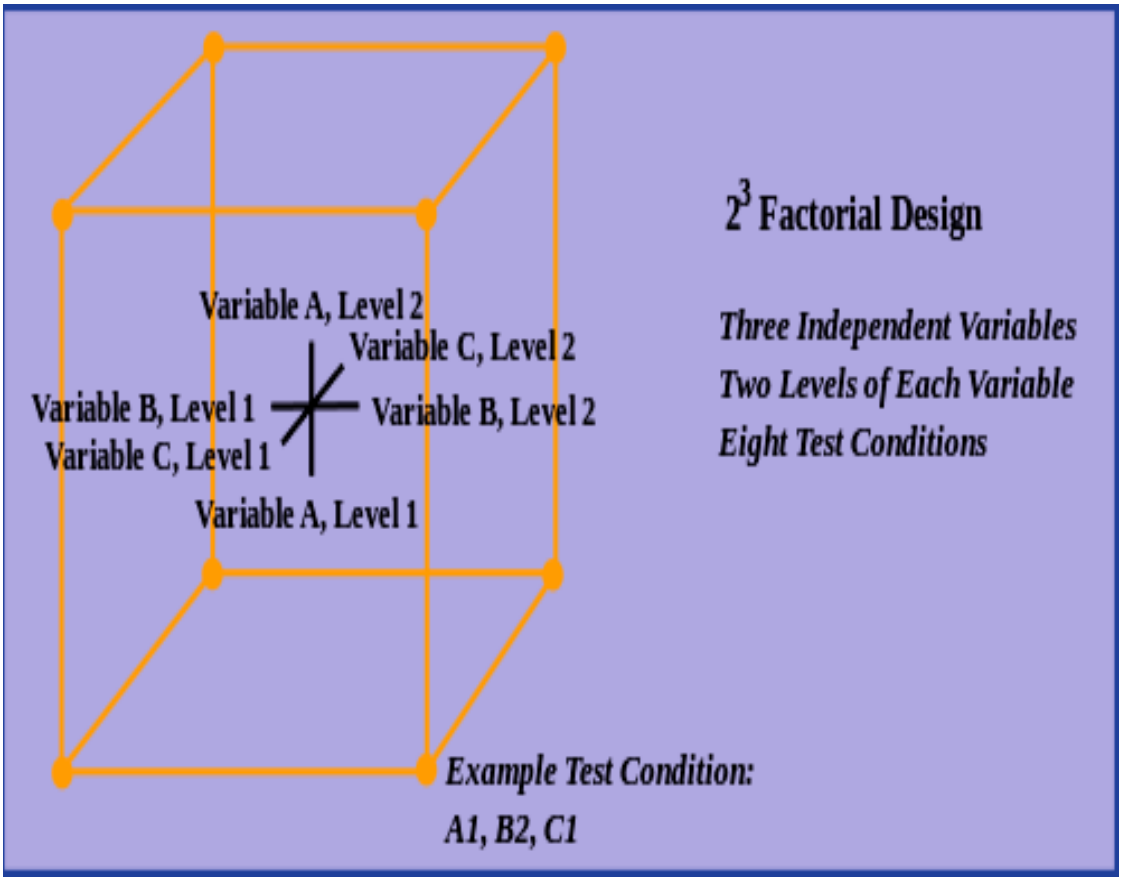
Website name:

_____

Website URL:

_____

Tutorial 3 – Experimental Design and its Applications



What is the Purpose of Tutorial 3?

- To understand experimental design and why it is useful in the field of engineering
- To be able to calculate the main effect and interaction effect of different combination of parameters
- To be able to plot the graphs of main effects, interaction effects and Pareto Chart

What is experimental design? Give some areas of application

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List all the fundamental steps of experimental design.

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Discuss three benefits of a good experimental design.

_____

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What is a hypothesis? Give an example of a hypothesis.

_____

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What are noise factors?

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Compare and contrast full factorial and fractional factorial designs.

Give three examples of fractional factorial systems. And state the formula for determining the total number of trials required.

What is a main effect and how can it be calculated?

What is an interaction effect? Give the mathematical expression for calculating interaction effects.

What is an interaction or profile plot?

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_____

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_____

An experiment was designed to investigate the sensitivity of an amplifier to process variation in order to determine if there are any element in the design that largely affect the output response due to their sensitivity. Three parameters were chosen in order to determine their effect on the Gain of the amplifier. These three parameters are; W the width of the microstrip lines), a resistor (R), and a capacitor (C). Results obtained are shown in the table below.

W	R	C	Gain
-1	-1	-1	12.85
1	-1	-1	13.01
-1	1	-1	14.52
1	1	-1	14.71
-1	-1	1	12.93
1	-1	1	13.09
-1	1	1	14.61
1	1	1	14.81

a) Looking at the results in the table above, what type of factorial design is this? Justify your answer.

_____

_____

_____

_____

b) Calculate the main effects of R and C.

_____

_____

_____

_____

_____

c) Calculate the interaction effects.

d) Plot the graph of main effects of R and C to the Gain

e) Plot the graph of interaction effects of W and R against the main effect of R

f) Create a Pareto Chart of all effect using Microsoft Excel

g) Which factor contributed most to the gain of the amplifier?

h) What is missing from the table of results in the previous page?

Tutorial 3 — Homework

Charmaine worked in the fruit and vegetable department of a grocery store in the afternoons. She wondered how much the ripeness of bananas affected the sale of the fruit. She decided to collect data for 10 days on the total number of pounds of bananas sold of green, yellow and brownish black bananas.

a) State an appropriate hypothesis for the experiment.

_____

_____

_____

_____

b) Identify the independent variable. Justify your answer.

_____

_____

_____

_____

c) Identify the dependent variable. Justify your answer.

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_____

d) Name variables that should remain constant for the experiment.

_____

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e) Use the table below to draw an appropriate graph

Degree of ripeness	Amount sold each day				
	1	**2**	**3**	**4**	**5**
Green	20	18	22	21	22
Yellow	40	38	37	43	40
Brown-black	10	12	9	10	8

f) What conclusion can be deduced from the data collected?

_____

_____

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_____

Mike is planning an experiment investigating the yield of a production process. He has 6 factors, D, G, X, B, T, Y, and he has two levels for each factor, low (-) and high (+), that he wants to try out. He would like to perform 16 experimental runs , where each experiment combines different settings of 6 factors.

a) Propose an experimental design for him , by writing down a table with 6 columns, each headed by the name of a factor, and with 16 rows, each consisting of "+" and "-" signs, indicating the levels of the factors for this experimental run. The experimental design should be balanced, so that each main effect and any interaction effects can be estimated independently.

b) Write the mathematical expressions for calculating the main effect of factor "D" and the interaction effect of factors "D" and "G"

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Tutorial 4 – Accuracy and Precision of Experimental Data

What is the Purpose of Tutorial 4?

- To understand the concept of precision/reliability and accuracy.
- To understand the concept of variability and its impact on reliability of experimental results.
- To understand that data obtained during experiments are subject to uncertainty.
- To investigate air resistance using paper helicopters.
- To explore how to make helicopter designs based on design settings.

In your own words, describe the meaning of the following terms:

- Variable

_____

_____

_____

_____

_____

- Dependent variable

_____

_____

_____

_____

- Independent variable

_____

_____

_____

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- Control variable

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- Accuracy

_____

_____

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- Precision

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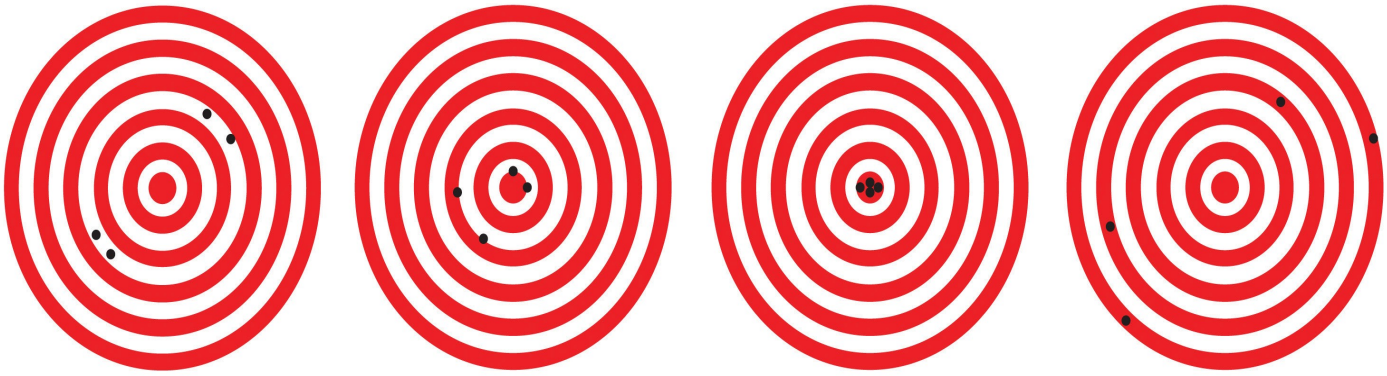
Accuracy is often expressed as an average of several measurements. Look at the target below. In your own opinion how well do the measurements on each target represent:

a) Accuracy?

b) Precision?

c) Reliability?

(Justify your opinion)



(a) (b) (c) (d)

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List as many parameters influencing the helicopter flight as possible

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Now categorise your design parameters.

Control	Noise

Discuss possible noise parameters you may not have control over.

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Investigation of Air Resistance using Paper Helicopters

Helicopter Design 1

	Trial 1	Trial 2	Trial 3	Trial 4	Average
Distance (m)					
Flight Time (s)					

Make an adjustment to your original paper helicopter design that you think will improve its flight. How or why do you think this adjustment will improve the time of flight of the helicopters?

_____

_____

_____

_____

_____

Helicopter Design 2

	Trial 1	Trial 2	Trial 3	Trial 4	Average
Distance (m)					
Flight Time (s)					

Did the design adjustments you made improve the time of flight of your helicopter? Why or why not?

_____

_____

_____

_____

Make an adjustment to your original paper helicopter design that you think will improve its flight. How or why do you think this adjustment will improve the time of flight of the helicopters?

_____

_____

_____

_____

Helicopter Design 3

	Trial 1	Trial 2	Trial 3	Trial 4	Average
Distance (m)					
Flight Time (s)					

Did the design adjustments you made improve the time of flight of your helicopter? Why or why not?

_____

_____

_____

_____

_____

Which of your helicopter designs worked the best and why?

_____

_____

_____

_____

_____

_____

Draw a diagram of your helicopter in flight. Label your diagram with the forces acting upon the helicopter in flight. Make sure to include terms such as thrust, lift, weight, and drag.

Tutorial 4 — Homework

Draw a target diagram that shows accuracy but not precision.

Draw a target diagram that shows precision but not accuracy.

Draw a target diagram that shows both precision and accuracy.

Discuss the reason why significant figures and decimal points are important when taking measurements in the laboratory.

_____

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Carry out a research on paper helicopter design (you may wish to check NASA website for comparison). Write down your findings/diagrams

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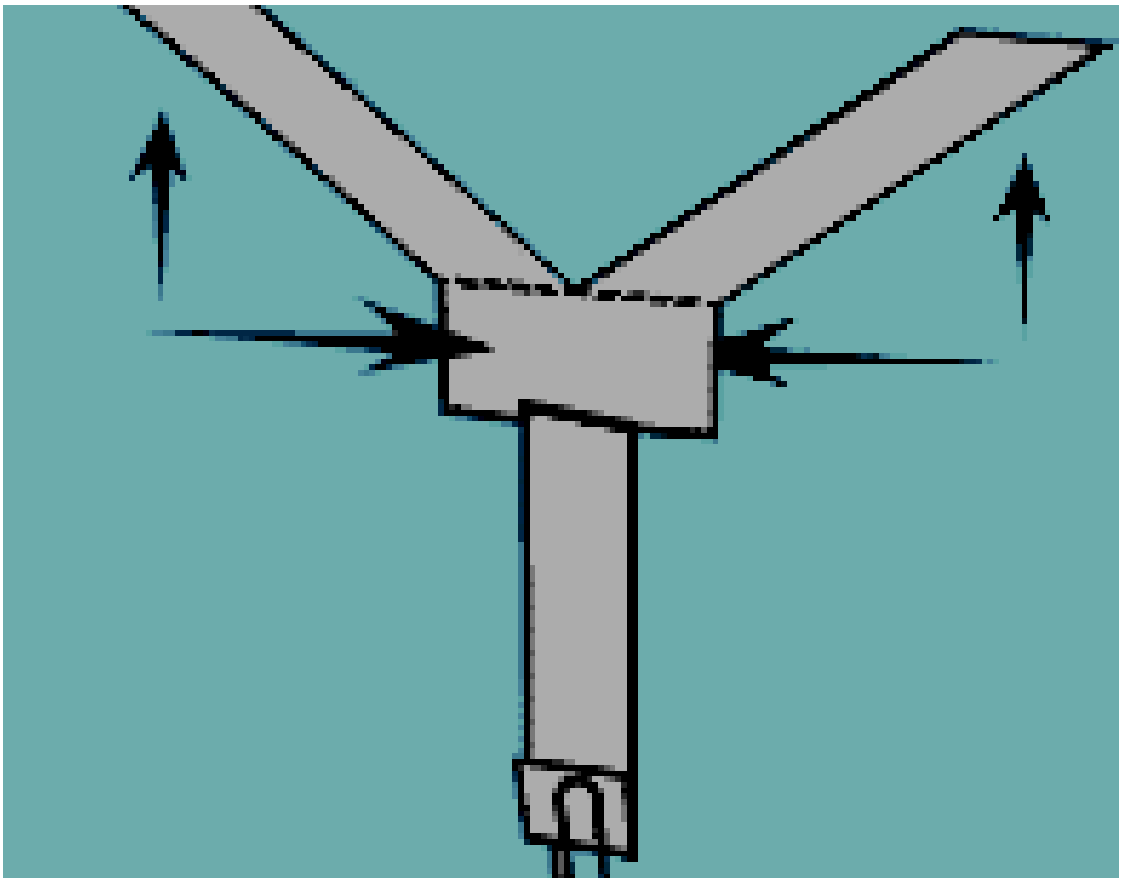
Tutorial 5 – Determining the Optimal Design Settings for Paper Helicopter Design



What is the Purpose of Tutorial 5?

- To understand the concept of experimental design and determine the optimal design setting of parameters
- To use fractional factorial design system in designing paper helicopters based on four or more factor combinations.
- To understand and interpret and present results obtained from flight pattern and time of flight.

Establish the exact details of your experimental procedure.

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_____

Design your table of results.

Prepare your paper helicopter, you may find it helpful to label each design.

_____

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Decide the height of drop and note it down

_____

_____

How many repeat trials do you need for the experimental results to be reliable?

_____

_____

Check with your tutor that your plan is recorded in sufficient detail in your course handbook using the blank pages overleaf.

Make a note of any noise factor.

_____

_____

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Notes

Notes

Tutorial 5— Final Assignment

For the final assignment, you will use the fundamental steps of experimental design to determine the optimal design setting of a paper helicopter or any other aircraft model of your choice. Using either full factorial or fractional factorial design in which the predicted relationships will be tested, you will design an experimental procedure that provides a theoretical representative context for this testing using appropriate *measurements, observations and interpretation of data*. You are required to produce a report which looks at the main effect and interaction effects of design settings. Following these steps and documenting the experimental design decisions you make, you should be able to write a research report which addresses the following questions/points:

- What is experimental design?
- What are the benefits of experimental design
- Describe a full factorial design and some fractional factorial example. Consider the pros and cons.
- Include a complete list of materials used
- Give a clear and concise account of the experimental procedure used.
- State quantities measured and define the number of measurements taken.
- Specify control measures adopted.
- Include a table of results - design settings may be represented by +/- symbols or similar.
- Include a table of results for the main effects and interaction effects using the spreadsheet provided.
- Data should be plotted correctly (you may include a Pareto chart).
- Include sample calculations of the main effect and interaction effects.
- Include possible sources of error and quantitative error analysis.
- Include all observations and an explanation of the science underlying your results
- Suggest which factor(s) are most important and why.
- Suggest further trials to optimise the helicopter designs.
- Include a brief conclusion linked to the aims of the experiment.

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.

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].

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.

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.

Appendix 2 – Using the VLE

VLE username	
VLE password	

Please remember the following key details:

You are able log into the VLE either through the link on our website (**www.thebrilliantclub.org**) or going directly to the VLE site at (https://portal.thebrilliantclub.org/sign-in).

- Please update your profile with your full name and email address- this will allow you to retrieve forgotten passwords or usernames

If you forget your log-in details you can request them to be emailed to you by clicking the link on the VLE home page. (If you are still having problems you can email: **schools@thebrilliantclub.org**)

What is the VLE?

The VLE is a virtual learning environment for all pupils on Uni Pathways it is used for:

messaging your tutor

submitting homework

submitting your final assignment

accessing resources for your tutorials

finding out more information about university and careers

How should I use the VLE?

The VLE is a professional academic environment in which pupils are able to message their PhD Tutor. Here are a few things to consider:

Ensure you keep a professional tone in the messages you send to your tutors.

Ensure you always reply to your tutors in a timely manner.

Thank your tutor for the effort they are putting in to give you your feedback etc.

Submit all homework to your tutor on time.

IMPORTANT: Final assignment

- When you submit your final assignment, please remember that you need to do so through the **'My Activities'** tab and not as an attachment to a message.

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