The Solar Shooting Gallery: Designing a Spacecraft for Space Weather Monitoring

Teacher Name: Dr Conlon

Pupil Name_____

Key Stage 4 Programme – 2016-2017

Timetable and Assignment Submission

Fill this in with your teacher.

Timetable – Tutorials

Tutorial	Date	Time	Location
1			
2			
3			
4			
5			
6			

Timetable – Homework Assignments

Homework Assignment	Description	Due Date
Tutorial 1		
Tutorial 2		
Tutorial 3		
Tutorial 4		
Tutorial 5		

Assignment Submission – Lateness and Plagiarism

Lateness	
Submission after 4.00pm on:	10 marks deducted
Plagiarism	
Some plagiarism	10 marks deducted
Moderate plagiarism	20 marks deducted
Extreme plagiarism	Automatic fail

KS4 Programme 2016-17 – 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 A-Level
2:2	50-59	Performing to an excellent standard at current key stage
3rd	40-49	Performing to a good standard at current key stage
Working towards a pass	0-39	Performing below a good standard at current key stage
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 RIS Teacher			
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 teacher should give an explanation in this section:

Learning Feedback Comment 1 - *Enter Key Learning Priority Here*	
What you did in relation to this Key Learning Priority *Enter feedback here*	**How you could improve in the future** *Enter feedback here*
Learning Feedback Comment 2 – *Enter Key Learning Priority Here*	
What you did in relation to this Key Learning Priority *Enter feedback here*	**How you could improve in the future** *Enter feedback here*
Learning Feedback Comment 3 – *Enter Key Learning Priority Here*	
What you did in relation to this Key Learning Priority *Enter feedback here*	**How you could improve in the future** *Enter feedback here*
Resilience Comment	
How you showed learning resilience during the course *Enter feedback here*	**How you could build learning resilience in the future** *Enter feedback here*

Example

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Course Rationale

“Space Weather” is an important and topical area of research currently taking place within the wider field of space science. This branch of science uses basic physical principles to observe and understand the interactions between the Sun and the Earth. Such interactions have the power to cause damage to man-made systems at Earth, in particular satellites and power grids. Damage to satellites for example can result in loss of mobile phone services, and loss of global positioning services among others. Damage to these systems can ultimately in some extreme cases even have the potential to cause direct loss of life. There is therefore a collaborative effort across many diverse branches of science to understand the processes involved, an effort that with its relevant specialities and rapidly growing space industry, the UK is taking a leading role in.

The overall aim of the course is for pupils to propose their own spacecraft mission to monitor some part of this Sun-Earth system. They will study topics relating back to various branches of physics they should be familiar with, such as dynamics and electromagnetism. More than this though, their proposal will be judged according to the same criteria used by ESA (the European Space Agency) to select their own missions. As a result, they will also have to consider the wider political and economic environment to sway the assessors if they are to see their own proposal accepted.

Course Map

Overview of the Sun-Earth system
How to structure a presentation
The Sun-Earth system in detail
The solar shooting gallery: Designing a spacecraft for space weather monitoring
Case studies: CLUSTER, STEREO and SDO
The wider context

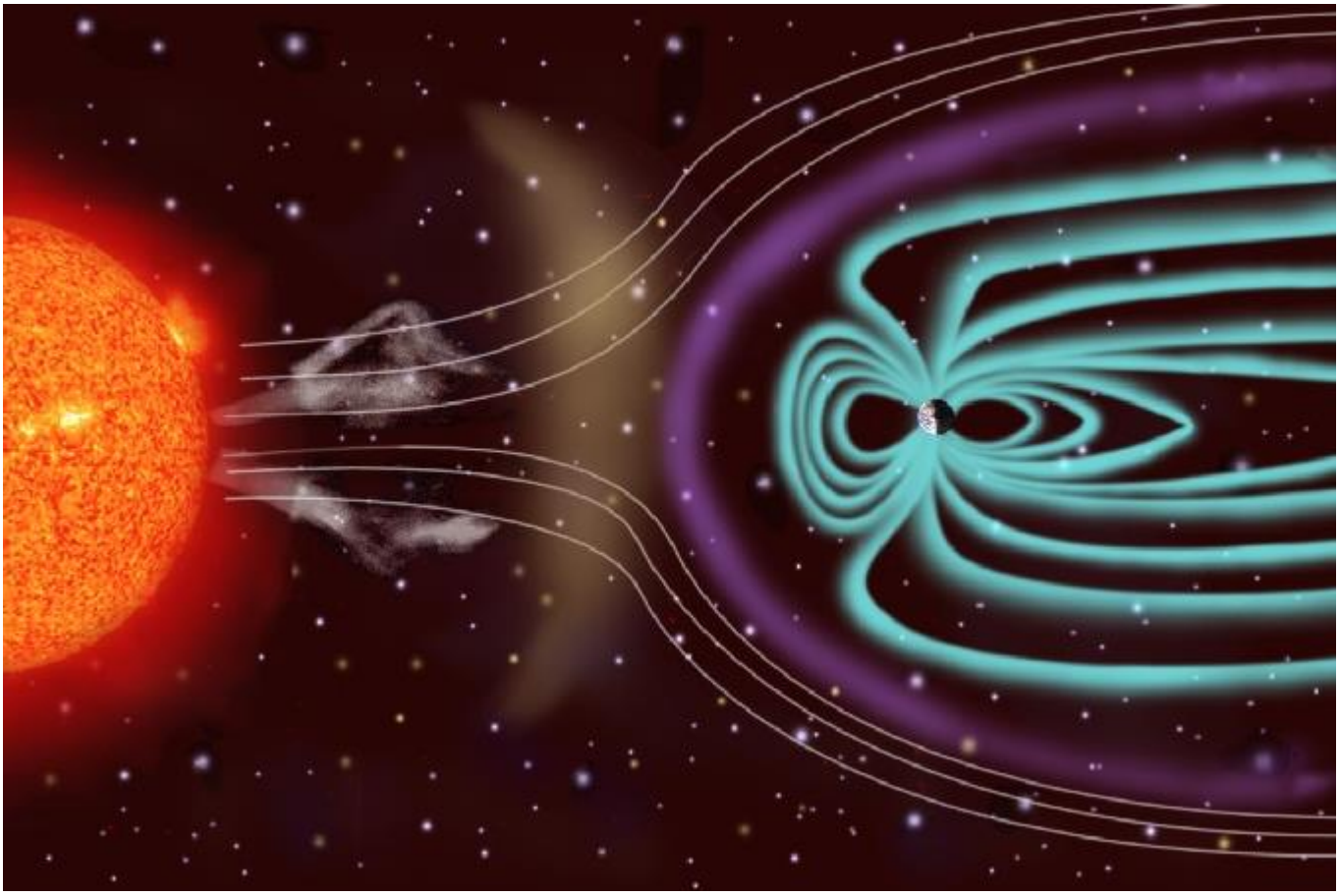
Mark Scheme

Key Skill	1st	2.2
Contextualising	Pupils thoroughly consider the wider economic and political climate into which they are submitting their proposal, and factor these considerations into their proposal	Pupils note the wider context into which they are making their proposal, but don't factor this into their proposal, perhaps designing their mission in spite of these factors
Numerical analysis	Pupils use relevant and sensible calculations to augment their case Calculations are used to discuss the merit (or otherwise) of their mission proposal	Calculations that are present are generally reproductions from another source, with little originality and few changes
Communication	Language is used to make their case compelling Technical language is generally used correctly and intelligently Layout used to make the content easier to understand Presentation is clear, and to time.	Spelling, punctuation and grammar are generally correct Presentation may not run exactly to time Presentation difficult to understand in places
Critical assessment	The various merits of the proposal are considered and weight against its disadvantages. This analysis linked back to previous calculations and comments Ways in which the mission fulfils the ESA brief are included	Some attempt is made at using the information provided in the presentation to justify the proposed spacecraft design
Bibliography and referencing	References used consistently and correctly Material that is not of the author's ownership is correctly referenced Bibliography is full and of sufficient detail	Some references are included, but they are few in number of the style is not consistent Bibliography is present

Glossary of Keywords

Word	Definition	In a sentence…
Frozen-in (magnetic field or plasma)	Used to describe particles in a plasma that have become fixed to the magnetic field. This means that if the magnetic field moves, the plasma moves with it and if the plasma moved, it drags the magnetic field along with it.	The Sun's magnetic field is frozen into the plasma of the solar wind, so that as the solar wind expands out into the solar system, it drags the Sun's magnetic field with it.
Gyromotion	The circular motion of a charged particle as it moved around a magnetic field line.	As an electron encounters a magnetic field, it's path curves so that a magnetic field line is at the centre of that curvature.
Heliosphere	The Sun's magnetosphere.	The extent of the expansion of the solar wind and where it encounters the interstellar wind defines the boundaries of the heliosphere.
Heritage	The use of older, previously tested technology on board a spacecraft.	The heritage of the telescope on the spacecraft could be traced back to Hubble. **Or** The instrument was used as it was a heritage instrument, as opposed to being new technology.
Interstellar wind	Analogous to the solar wind, this is the flow of particles that dominate the space beyond the heliosphere (solar system).	When the solar wind collides with the interstellar medium, you have reached the boundary of the heliosphere.
Ionisation	The process of removing an electron from the atom of a gas.	Heating up a gas leads to ionisation, which results in a plasma.
Ionisation potential	The energy required to ionise an atom.	The ionisation potential of hydrogen is about 13.6 eV.
Magnetosphere	The region of space that is dominated by the magnetic field of a particular celestial body.	The magnetosphere of the Earth is the region of space dominated by the Earth's magnetic field.
Plasma	The fourth state of matter, a plasma is an ionised gas, and on Earth is usually obtained by heating up a gas.	As it has been ionised, a plasma reacts to the presence of electric and magnetic fields.
Redundancy	Whether or not a spacecraft has a backup to a particular system, in case the original system fails.	The presence of two telescopes on the spacecraft built redundancy into the mission.
Single-point failure	A single failure in the spacecraft that would completely shut down the spacecraft mission.	As there is no back up power system, the total failure of the panels would be an example of a single-point failure.
Solar wind	The Sun's atmosphere as it expands into the solar system.	The solar wind flows past the planets and out to the very limits of the solar system.

Tutorial 1 – Overview of the Sun-Earth System



Today's Key Question(s):

- What is space weather?
- How do conditions at the Sun affect us here on Earth?

What is the Purpose of Tutorial 1?

- To introduce the topic and the course structure
- To introduce the Sun-Earth system
- To give a qualitative description of the Sun-Earth system

Today's Homework is:

- Baseline Assessment

Context

Modern society has become heavily dependent on satellites and electricity power grids for its power and communication needs. These systems can be adversely affected by conditions in the Earth's near space environment. These conditions are collectively referred to as "space weather". The Earth's space weather is sensitive to conditions at the Sun. This tutorial will qualitatively describe how conditions at the Sun affect those at the Earth. By the end of this series of tutorials, you will propose a spacecraft design that could be launched with the purpose of monitoring space weather.

What is "Space Weather"?

Space weather is a term used to describe the conditions in the Earth's near space environment. Many of the words and phrases used to describe this are borrowed from meteorology (weather forecasting) and there are even suggested links between space weather and terrestrial weather. In the same way that a storm indicates some extreme terrestrial weather conditions, a space weather storm (called a geomagnetic storm) indicates extreme conditions in the region of space close to the Earth.

What are the dangers of space weather?

The primary dangers posed from extreme space weather consist of damage to man-made systems, especially satellites. Modern society has become very reliant on communication systems that rely on the presence of satellites. A geomagnetic storm can cause damage to such satellites and knock out communication systems. In very extreme cases there can be more visible signs of damage here on Earth. The largest geomagnetic storm on record for example tool place in 1859 and was able to set fire to power cables on Earth. From the middle of the 20th century however there has been another risk. Extreme examples of space weather can also increase the radiation levels around the Earth. This is of potential concern to astronauts. Fig. 1 shows a graph. On the horizontal axis is the period of time encompassing the mid to late Apollo missions, which were manned missions to the moon. On the vertical axis is the radiation dose, with various horizontal coloured lines showing the effect on the human body of that particular radiation dose. The red line indicates a fatal dose. The vertical yellow/orange lines indicate storms with particularly high levels of accompanying radiation. The blue vertical lines labelled with numbers show the time of that particular Apollo mission. Some of these missions are quite close in time to spikes in radiation level. This results in a health risk for the astronauts. If for example Apollo 16 had been launched a couple of months later, the entire crew could have experienced a fatal dose of radiation.

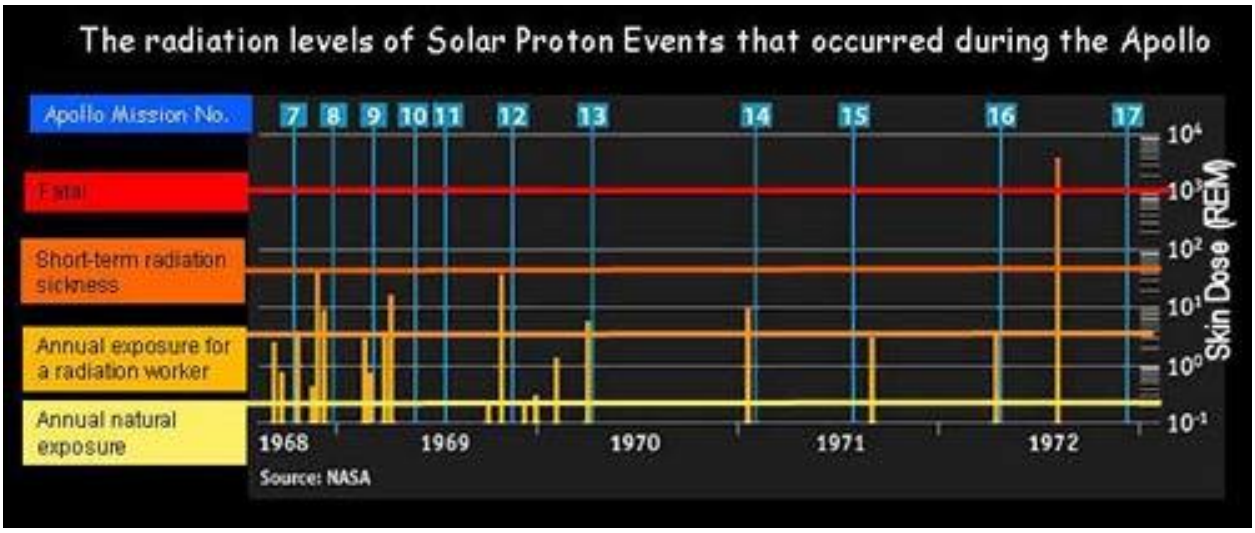


Fig. 1: The radiation levels that occurred during the timeframe of the Apollo missions to the Moon.

Homework 1 – Baseline Test

The homework assignment for the first tutorial is a baseline test to see your initial level of attainment in this subject area. The assignment will test for some of the subject specific skills that are required later in the final assignment. The questions are outlined below, but your answers should be submitted on paper. Don't worry too much about doing 'well' or 'badly' on the baseline test, it takes into account the fact that you may not be familiar with the subject area. It is designed to help you and your teacher identify where you are at the start of the programme and to help you measure your progress along the way.

Please answer these questions on a separate sheet of paper, including your name, and hand it in by the deadline discussed in the first tutorial.

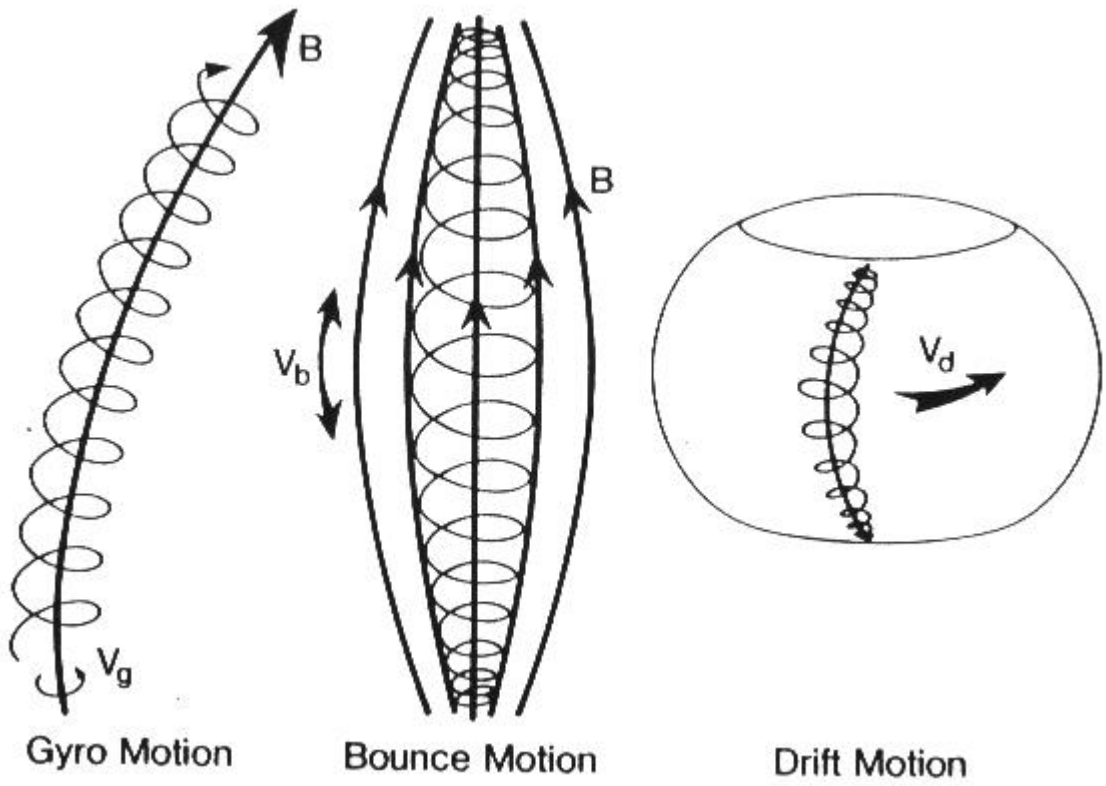
Electricity:

1) There are three types of constituent particles that make up an atom. What are they?
2) What is electrical current the flow of?
3) What units are used to measure electrical field strength?
4) Draw the electric field between two parallel, flat plates of opposite charge.
5) On the diagram from question 4, draw the direction of the force exerted on a proton placed in that electric field.
6) On the diagram from question 4, draw the direction of the force exerted on an electron placed in that electric field.
7) F=qE. Use this to calculate the force exerted by an electric field of strength 50 V/m on a proton.
8) Using the equation in question 7, calculate the electric field that would cause a helium nucleus to experience a force of 20 N.

Magnetism

1) Magnets have two poles. What are they called?
2) What happens if you try to bring together the like poles of two magnets?
3) What happens if you try to bring together the opposite poles of two magnets?
4) Some iron filings are spread evenly over a piece of paper. A bar magnet is placed on top of them. Draw the magnet and resulting pattern that the filings form.
5) Draw a bar magnet and the magnetic field around it.
6) F=Bqv. What force is experienced by an electron moving at a speed of 330 m/s in a magnetic field of 2 T?
7) In what direction does the force from a magnetic field act relative to the magnetic field itself?
8) Draw the motion of a single charged particle around a single magnetic field line.

Tutorial 2 – The Mechanics of the Sun-Earth System



Today's Key Question(s):

- How does the Earth's magnetic field protect the planet from the solar wind?

What is the Purpose of Tutorial 2?

- To use the results of the baseline assessment to recap some fundamental physics
- To examine and explore the physical processes and mechanics that cause the interactions discussed in tutorial 1

Introduction

In the last tutorial we looked at some general qualitative descriptions of space weather. In this tutorial, we are going to look at some of the mechanics in a little more detail.

In addition to the three states of matter that you are familiar with (solid, liquid, gas), there are others. We are going to be considering the forth state of matter, the plasma. In a material, there are bonds between the different atoms that hold the material together. As a solid, those bonds are at their strongest. When you heat a solid, you weaken those bonds, and you get a liquid. If you heat the liquid, you break those bonds and form a gas. Each of these stages takes energy. What happens then when you heat up a gas? There are no longer any bonds to break between atoms, so you start to break bonds within atoms, and you get a gas made up of a lot of electrically charged particles. This is known as a plasma. Each of these states of matter can be seen in Fig. 2 below. The temperature at the Sun is high enough that it is composed of a plasma. The atmosphere of the Sun continually expands into the solar system, and this expansion is called the *solar wind*. When the charged particles that make this up reach the Earth, they interact with the Earth's magnetic field.

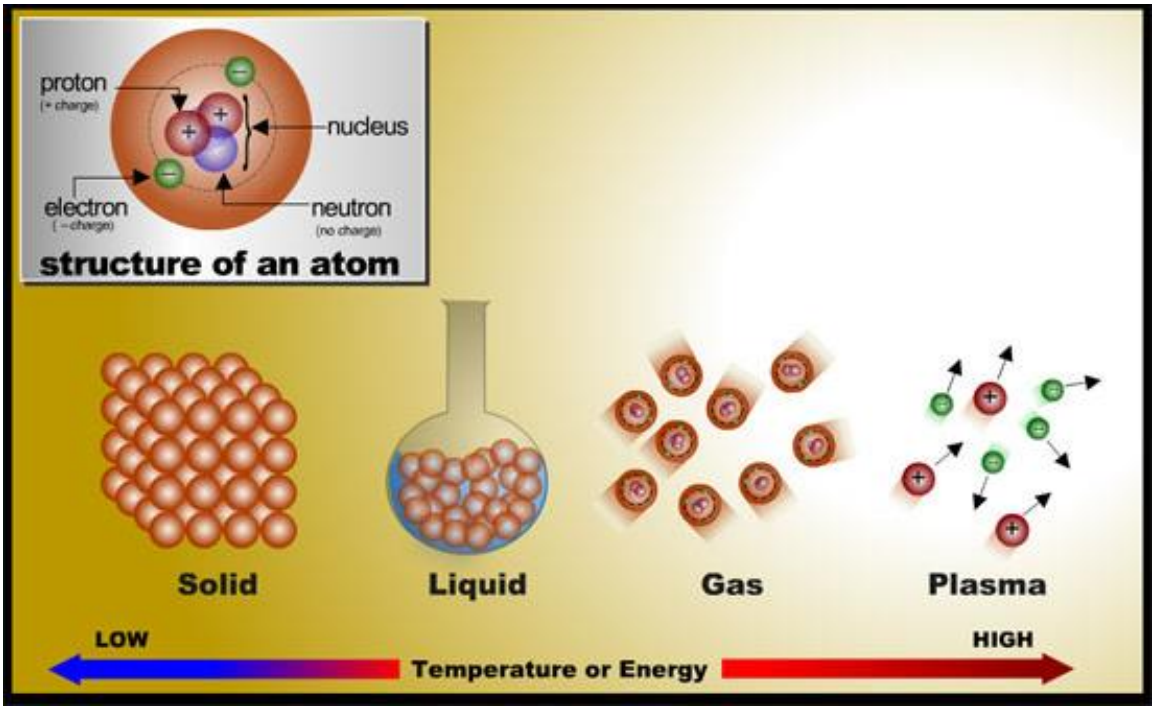


Fig. 2: Showing the four different states of matter; solid, liquid, gas, plasma.

Interaction with magnetic fields

Charged particles follow trajectories that make them orbit magnetic field lines, as can be seen in Fig. 3. This motion means that the charged particles from the solar wind get trapped in the Earth's magnetic field rather than moving down to the Earth's surface.

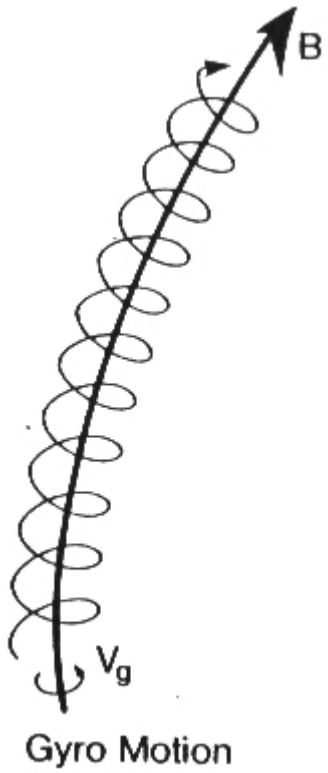
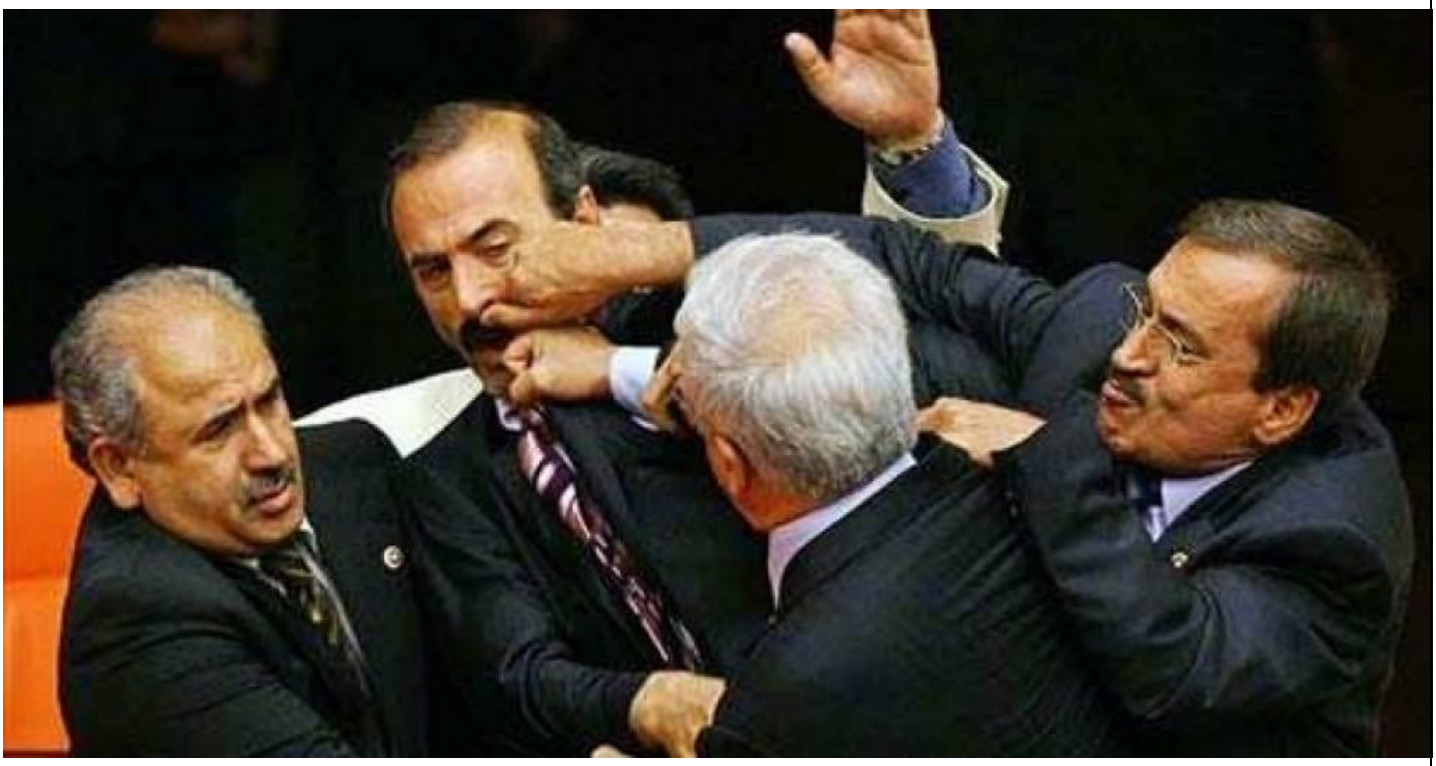


Fig. 3: The motion of a charged particle around a magnetic field line.

Today's Homework is:

- Use whatever resources you feel are appropriate (the internet is a great place to start) to research historical space missions and spacecraft. As you do your research you should be looking to answer a couple of questions:
    1. What are the features of a successful space mission?
    2. What are the reasons that a particular mission is not successful?
- Bring your research to the next tutorial.

Tutorial 3 – The wider context



Today's Key Question(s):

- What makes a successful space mission?

What is the Purpose of Tutorial 3?

- To understand the wider political context that space missions fly into and are selected against
- To understand the wider economic context that space missions fly into and are selected against
- To understand common criteria used to select one spacecraft mission and not another

Introduction

There are a wide variety of factors that contribute to the success or failure of a particular spacecraft mission. These can generally be split into a few main categories:

- Scientific
- Engineering
- Political
- Economic.

In this tutorial, we will take a look at each of these categories and consider how they impact on a spacecraft being successful or not.

Scientific

Generally, a spacecraft will be designed with a specific objective, often scientific in nature. If the spacecraft us judged to be inferior to another spacecraft at completing its objective then it will not be selected.

Engineering

These are normally practical considerations. If it is judged that there are design features of a spacecraft what are likely to fail, that it is unlikely to be selected. For this reason, spacecraft are often designed to use components that have flown on other

spacecraft before and so have been tested in the extreme environment that space provides. Where the components originally come from is called a spacecraft's heritage.

Political

There are always political considerations when designing a spacecraft. These can often be difficult to manage as modern spacecraft take decades to move from a concept stage to being launched, and that time period will see many political changes occur. One of the most controversial decisions in recent years involved designing a spacecraft (NASA's "New Horizons" mission) with a nuclear power source. This sparked a great deal of political debate over whether a spacecraft should be launched with radioactive material on board. Eventually, the mission was launched, but the choice of power source almost got the mission cancelled.

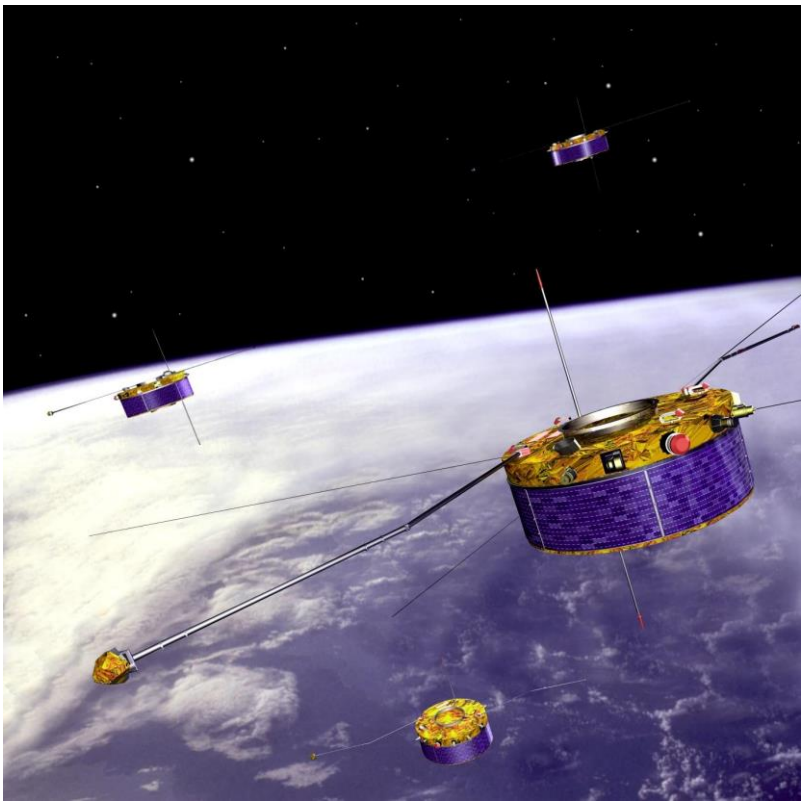
Economic

All space missions have to be funded, and often that funding is provided by a national government, although increasingly that money is also coming from private companies. In our currently economic environment, space agencies are having to be very careful with their money. This means that they are favouring smaller, cheaper missions over large, more expensive ones. The days of Hubble-like missions appear to be over, at least for now.

Today's Homework is:

- Briefly research three space weather related missions (for example the NASA's SDO and STEREO missions or ESA's CLUSTER mission). Make notes on each about which parts of the Sun-Earth system they investigate, and each spacecraft's strengths and weaknesses. In the next tutorial we will discuss the missions.

Tutorial 4 – Space mission case studies



Today's Key Question(s):

- Which aspect of the missions discussed can I incorporate into my own proposal

What is the Purpose of Tutorial 4?

- Discuss in detail the case study missions
- Give the students some ideas to help with their own mission proposals

In this tutorial, we are going to be looking at some examples of existing spacecraft missions. As we are discussing them, you should be thinking about what you would like your mission to do and whether you can incorporate any features from the missions we discuss into your own proposal.

NASA's Solar Dynamics Observatory (SDO)

A single spacecraft launched by NASA to provide high quality images of the Sun. This is one of the most recent examples of a large, expensive spacecraft.

NASA's Solar TErrestrial Relations Observatory (STEREO)

A pair of near identical spacecraft designed to image the Sun and solar wind from radically different perspectives. The spacecraft have been designed to be as cheap and economical as they can.

ESA's Cluster mission

A European mission consisting of 4 near identical spacecraft. Again, it was designed to be relatively economical and thus was restricted to in-situ measurements only.

Today's Homework is:

- Presentation notes. These will be submitted when you present your mission proposals, and should provide more detailed information regarding your proposal that you will not have time to give in your presentation.

Tutorial 5 – Structuring a presentation

Today's Key Question(s):

- How can I make my presentation as effective as possible?

What is the Purpose of Tutorial 5?

- To look through the students' presentation notes and give some feedback based on these
- Give advice regarding the presentations and some examples of good practice
- Answer any questions regarding presentations

In this tutorial, we are going to take a look at making and giving a presentation and what can make it more successful, interesting and informative. This will also be your opportunity to ask any questions about the final presentations that you want to.

Today's Homework is:

- Prepare the final assessment, the presentation, ready for the final tutorial session.
- Finalise your presentation notes.

The Deadline is:

Tutorial 6 – Feedback

What is the Purpose of Tutorial 6?

- Reflect on skills learned on the programme with a view to encouraging resilience
- Receive feedback on final assignment

What are the key questions?

- What strengths have I demonstrated in my work and what areas of development are there left for me to address?
- What steps do I need to take to improve my academic output?

Activity 1 – Marking your own

Using the mark scheme, identify three things you did well and three things you could improve.

What went well?

1.

2.

3.

What could be improved?

1.

2.

3.

Activity 2 – Responding to feedback

Read through your feedback sheet and highlight on your assignment where you received positive feedback (one colour) and areas for improvement (different colour). You might find it helpful to annotate this with a brief comment or two.

Activity 3 – Looking Forwards: Think, Pair Share

1. Think about how you can use this feedback in your future school work.
2. Talk to your partner about how you both plan to make changes to your school work in the future as result of this feedback
3. Share your ideas as a group.

Appendix 1 – Referencing correctly

Appendix 1 – Referencing

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 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:

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].

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 – University Applications Guidance

For course choices and careers information:	www.brightknowledge.org.uk
For information and statistics on universities and course:	www.unistats.direct.gov.uk
For comprehensive information on universities, including rankings:	www.thecompleteuniversityguide.co.uk

PLEASE NOTE – The Researchers in Schools programme is designed to support the university applications process at your school. The work you complete for the programme should add to your schoolwork rather than detract from it. Please be aware of deadlines and try to manage your workload appropriately. If you are worried about the programme interfering with your schoolwork then please speak to your teacher.

Subject Specific Top Tips for Strengthening an application?

1. Be clear which subjects at A-level you require for your desired degree. It is not always obvious.
2. Take at least 2 "facilitating A-levels". These tend to be core academic subjects (Maths, Sciences, Languages, Humanities) and will leave you a lot of flexibility when deciding which degree programme to select.
3. Attend as many University open days and events as you can.
4. Try to do some work over the summer holiday that is relevant to the degree you would like to do. For example, you might decide to try and get a summer internship with a pharmaceuticals company if you were interested in studying Chemistry.