Researchers in Schools

What do black holes and neon lights have in common?

Key Stage 4 Programme

Pupil Name	
Coursebook Designed by	DR WHARTON

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Uni Pathways launch event

Welcome to Uni Pathways! We are delighted to be able to launch the Uni Pathways programme with you. We hope that you are ready to embark on your Uni Pathways journey and that you enjoy the video.
You will be asked to pause the video at times to complete some work in this workbook, so make sure you have a pen / pencil to hand when you start the video.

By the end of the video, you will have

- Learnt about what studying at university means
- Learnt about some of the skills that you will develop during Uni Pathways
- Heard from pupils who have participated in Uni Pathways or The Scholars Programme (which is the same programme!)
- Heard from current university students talking about what life is like at university

If you are in school your teacher will play the video. If you are at home and logged in to a session with your teacher, your teacher will play the video and show it to you. If you are participating independently your teacher will email you the link to the video or the video file. There are opportunities for you to answer some questions, and you will be told when to pause the video to answer them.

Introduction to Uni Pathways

1. Write down what you think a supra-activity is

_____
_____
_____

2. Independent learning is

_____
_____
_____

3. Write down in your own words what resilience means, and come up with a different example to the one mentioned in the PowerPoint.

_____
_____
_____
_____

4. Why do you think analysis and evaluation skills are useful in your academic career? _____
_____
_____
_____
_____
_____

5. Why do you think analysis and evaluation skills are useful in life in general? _____
_____
_____
_____

6. What are the different types of learning that university students do?

Pupils' experience of Uni Pathways
You will now watch some pupils talk about their experience of learning a PhD topic and producing a final assignment. Some may refer to The Scholars Programme rather than Uni Pathways. As you heard in the introduction PowerPoint, The Scholars Programme is a very similar programme to Uni Pathways. Listen carefully and then respond to the questions below. Be prepared to share some of your responses with your peers.

1. How did the pupils describe talking about writing a long essay for their final assignment?

2. Write down something that one of the pupils mentioned was particularly interesting in their course.

3. What were some challenges that the pupils met?

Virtual campus tours
You will now go on a virtual tour of some universities! Once you have seen some of the university campuses, respond to the questions below.
Note down something that you liked out of any of the campus tours you saw. It may be a particular building, space, city etc.

1. Were there any similarities between the different university campuses? If so, what are the similarities?

2. If you had to pick one of those universities to go and visit in person, which one would it be and why?

3. Note down some of the societies that you could join at different universities

Meet university students!
You are about to virtually meet or hear from some current university students.
If you are virtually meeting them, think about what questions you would like to ask the students, share your questions with a partner and note those questions down in the space below.

If you are not meeting them but watching some videos that they have made, use the space below to note down what else you would like to find out about university. You can then ask your teacher during Uni Pathways tutorials!

Reflection
Congratulations on completing the launch of the Uni Pathways programme. Before you go, take some time to reflect on what you have learnt by answering the following questions:

1. Are there any aspects of university style learning that you would look forward to? If so, what are they?

2. What challenges do you think students face when learning at university? How would you try to overcome these challenges?

3. What skills do you hope to develop during your Uni Pathways course?

4. What part of Uni Pathways seems the most challenging for you?

5. What are you most looking forward to about Uni Pathways?

Timetable and Assignment Submission

Timetable – Tutorials

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

Timetable – Homework Assignments

Homework Assignment	Description	Due Date
Tutorial 1	Baseline Assignment	
Tutorial 2	A Day at the Races	
Tutorial 3	The Electrolaser	
Tutorial 4	Fun Facts	
Tutorial 5	Final Assignment	

Assignment Submission – Lateness and Plagiarism

Lateness	
Submission after the deadline	10 marks deducted
Plagiarism	
Some plagiarism	10 marks deducted
Moderate plagiarism	20 marks deducted
Extreme plagiarism	Automatic fail

Course Rationale

What do nuclear bombs, the Sun, black hole jets, neon lights, radio communications, the northern lights and lightning all have in common? They all involve plasma!

The course aims to introduce students to plasmas, which compose 99% of ordinary matter in the universe. The course will start by considering what the constituent parts of the universe are and where solids, liquids, gases, and plasmas fit into that picture.

The students will learn about a range of different plasmas that exist in the universe and what their properties, and in some cases, uses are. The main properties they will learn are density, temperature, degree of ionization and composition.

From a physical perspective, they will learn what plasmas are and how they are created by either heat or ionizing radiation. They will also learn how they interact with electromagnetic fields and how this knowledge can be used to control them.

The course aims to consolidate the student's prior knowledge of atomic structure, heat, ionization, and electromagnetic fields to understand this state and its place in the universe. They should also develop basic research skills to learn in more detail about a specific plasma.

Uni Pathways Mark Scheme 2020 – science-based assignments

	Subject Knowledge	Critical Thinking	Written Communication
1st	The work shows a depth of knowledge and understanding of key concepts and scientific methods, through engaging with relevant sources. Knowledge is used to build and support highly effective scientific arguments and explanations.	Analyses key scientific evidence, arguments, and reasoning. Interprets meaning and makes connections. Identifies and critically evaluates key scientific arguments and evidence, deciding on their credibility, strength, and relative significance, drawing convincing conclusions.	The work has a coherent flow and is well structured. The writing style is appropriate; scientific language and key scientific terms are used accurately and effectively to support the arguments and explanations made. There are no, or very few, errors in spelling or grammar. Consistent referencing, appropriate paragraphing and use of correctly labelled tables and graphs matching the style taught in the course.
2:1	The work shows an understanding of key concepts and scientific methods, drawing on relevant sources. Knowledge is used to build and support effective scientific arguments and explanations.	Analyses relevant scientific evidence, arguments, and reasoning. Identifies and critically evaluates relevant scientific arguments and evidence, deciding on their credibility and strength, drawing reasonable conclusions. Shows some understanding of the relative value of evidence and arguments.	The work is well-structured. The writing style is appropriate; scientific language and key terms are used correctly. There are few errors in spelling or grammar. Mostly consistent referencing and use of tables and figures; matching the style taught in the course.
2:2	The work shows an understanding of key concepts and scientific methods, with no major misconceptions. Beginning to apply this knowledge to build and support effective scientific arguments and explanations.	Identifies and uses basic scientific evidence, arguments, and reasoning. Showing some understanding of the quality of scientific arguments and evidence. Not yet showing understanding of the relative value of evidence and arguments.	The work has some structure. The writing style can sometimes be informal; occasionally scientific language and key terms are not used when it would be appropriate to do so. There are some errors in grammar and spelling do not get in the way of communicating the content. Referencing has some consistency; matching the style taught in the course Limited use of tables and graphs.

3rd	Shows a developing understanding of key concepts and scientific methods, with some misconceptions. Does not yet apply this knowledge to build and support scientific arguments and explanations.	Beginning to analyse scientific evidence, arguments, and reasoning. Describes evidence and arguments, while not yet evaluating them.	The grammar, spelling, style, and structure of the work need improving in order to communicate ideas to the reader. Scientific language, key terms and references are not always used correctly. Limited, or no use of tables and graphs.

Baseline Assignment (problem-set): Pupil Feedback Report

Name of Pupil	
Name of School	Fullhurst Community College
Name of RIS teacher	Dr Wharton
Title of Assignment	A Question of Scale/What is the space weather looking like tomorrow?

How your assignment is graded:

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 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

Marks

OVERALL MARK / 100		FINAL MARK / 100 (including any deductions)	
DEDUCTED MARKS		FINAL GRADE	

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

Mark Breakdown and Feedback

Subject knowledge	
	mark
Critical thinking	
	mark
Written communication	
	mark
Problem Set	
Comment	*mark*

Final Assignment (problem-set): Pupil Feedback Report

Name of Pupil	
Name of School	Fullhurst Community College
Name of RIS teacher	Dr Wharton
Title of Assignment	The Physics of Plasmas/My Favourite Plasma

How your assignment is graded:

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 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

Marks

OVERALL MARK / 100		FINAL MARK / 100 (including any deductions)	
DEDUCTED MARKS		FINAL GRADE	

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

Mark Breakdown and Feedback

Subject knowledge	
	mark
Critical thinking	

	mark
Written communication	
	mark
Problem Set	
Comment	*mark*

Subject Vocabulary

Word	Definition	In a sentence
Plasma	A state of matter in which atoms have become ionised to create a mixture of ions and electrons.	A plasma is produced by heating up a gas until its atoms or molecules become ionised.
Electric Field	A volume of space created around and by a charged particle where it can exert a force on other charged particles.	The electric field of a positively charged particle will result in a repulsive force on other positively charged particles and an attractive force on negatively charged particles.
Magnetic Field	A volume of space created around and by a moving charged particle where it can change the direction of another charged particle but do no work on it.	Charged particles in the Earth's magnetic field will experience a force and change direction, but their speed will not change.
Radiation	The transmission of energy through space by either waves or particles.	The hot light bulb emitted radiation in the form of electromagnetic waves.
Electronvolt	A unit of energy equal to accelerating an electron through a potential difference of one volt.	The proton had a kinetic energy of 10 electronvolts.
Ionization	The process of turning an atom into an ion by adding or removing electrons from the atom.	The X-rays ionised the hydrogen atom, turning it into a proton and an electron.
Quasi-neutrality	Although the plasma is composed of positive ions and negative electrons, the overall charge of the whole plasma will be zero if it is large enough, making it electrically neutral.	The solar wind has enough protons and electrons to make it quasi-neutral on a large scale.
Charge	A property of a particle which allows it to generate electric and magnetic fields, as well as interact with the electric and magnetic fields of other charged particles.	An electron has a charge of -1.6×10^{-19} C and a proton has a charge of 1.6×10^{19} C.
Centripetal Force	Any force which acts at right angles to the direction of travel of an object, which causes that object to move in a circle.	A magnetic field exerts a centripetal force on a charged particle, which causes it to move in a circle or helix.
Gyration	Any motion that results in an object or particle moving around a fixed line in a circular or helical motion.	The magnetic field caused the proton to gyrate around the magnetic field line.

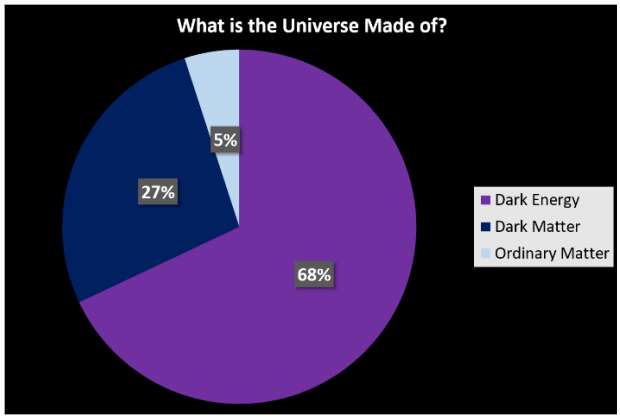
Energy	The work available to a force that allows it to move something else.	Energy cannot be created or destroyed but is changed from one form to another by forces.
Kinetic Energy	The work available in a particle because it is moving.	The fast proton had a large kinetic energy.
Potential Energy	The work available in a particle because of its position in a field.	The ball had a lot of potential energy at the top of the building because of its position high up in the Earth's gravitational field.

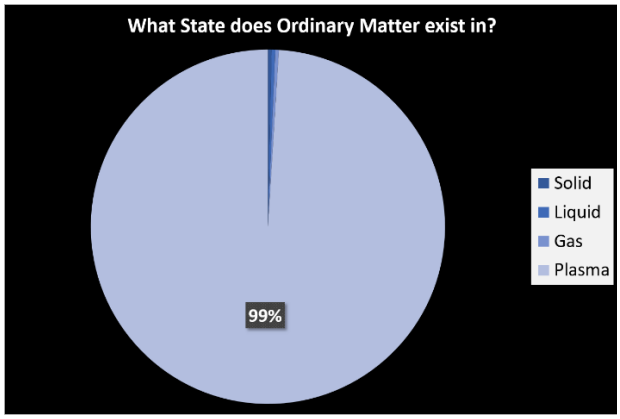
Tutorial 1 – The Role of Plasmas in the Universe

What is the Purpose of Tutorial 1?

- I will know what the main types of matter are in the universe and how much of it is in the plasma state
- I will know what the main particles of ordinary matter are
- I will be able to describe how plasmas are created
- I will understand that some plasmas exist naturally and others can be created artificially for certain uses and I will know some examples.

1. Starter - So what do you think the universe is made of?





2. What are the main particles that make up ordinary matter?

3. So… do you know what a plasma is?

a) What is a plasma?

b) How do I make a plasma?

c) What does ionize mean?

4. Think, pair, share!

If plasmas make up so much of the universe, why are we not familiar with them?

Discuss with your partner and write down your thoughts

Baseline Assignment

Part 1: A Question of Scale

1. In tutorial one, we discussed what the universe was made of. We found that only 5% of the matter in the universe is ordinary matter that we could see. The rest is mysterious dark matter and dark energy. Of the ordinary matter, 99% of it is plasma, the rest being solids, liquids, and gases.

   How much of all the matter in the universe is plasma? Give your answer as a percentage.

   In what kind of object would you find most of this plasma?

2. a) If; $10^1 = 10$
   $10^2 = 100$
   $10^3 = 1,000$

   What is 10^{20} written out in full?

   b) If; $3 \times 10^4 = 30,000$
   $3.1 \times 10^4 = 31,000$
   $3.15 \times 10^4 = 31,500$

   What is 7.023×10^{11} written out in full?

   c) If; $5 \times 10^{-1} = 0.5$
   $5 \times 10^{-2} = 0.05$
   $5 \times 10^{-3} = 0.005$

   What is 1.6×10^{-19} written out in full?

   d) The numbers on the left in all of the above expressions are written in *standard form*. Writing numbers in standard form is a very useful way of expressing extremely large or extremely small numbers in a concise way.
   For example, the mass of an electron is 9.11×10^{-31} kg. Written out in full, this is 0.000000000000000000000000000000911 kg!
   The mass of the sun is 1.989×10^{30} kg. Written out in full, this is 1,989,000,000,000,000,000,000,000,000,000 kg!
   Hopefully, you can see the advantage of writing numbers in standard form. Your calculator can switch between normal numbers and standard form easily using the "S ⇔ D" button.

   Write the following numbers into standard form:
   12,000
   1,230,000,000
   0.0000033

Part 2: What is the space weather looking like tomorrow?

The sun gives out a continuous stream of hot plasma called the solar wind. The solar wind can interact with the Earth's magnetic field and cause a range of disturbances, including the aurora (Northern lights). These disturbances are collectively called *space weather*. Your task is to write a short space weather forecast for the next few days. You may use the resources at the bottom to help you.

Success Criteria:

In your report, you should include some information about what the sun is doing: e.g. are there any *sunspots*? Are there any *active regions*? Are there likely to be any *coronal mass ejections*?

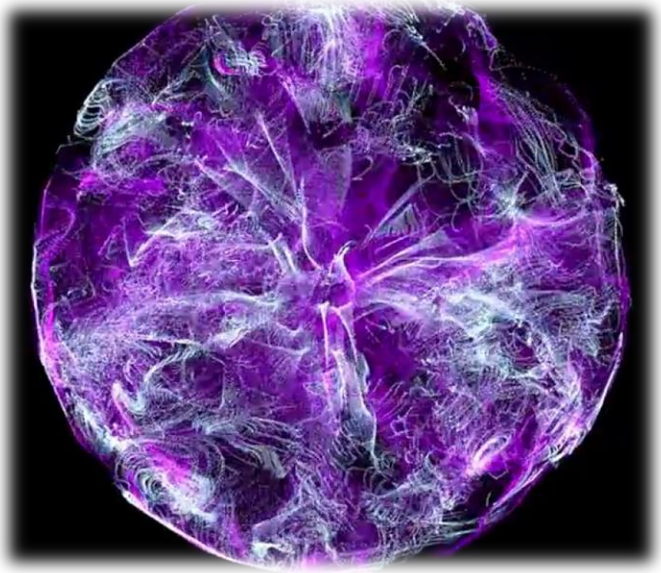
You should also include a forecast for the *aurora*, which are enhanced when there is a lot of space weather.

If you can explain what some of these phenomena are, you will gain higher marks. All of the phenomena mentioned involve plasma.

You should aim to write a maximum of 500 words and include some useful images. Any text should also be written in full sentences with correct spelling and grammar.

Useful Resources:
https://www.metoffice.gov.uk/weather/specialist-forecasts/space-weather
https://www.swpc.noaa.gov/products/aurora-30-minute-forecast
https://www.swpc.noaa.gov/products-and-data
https://www.swpc.noaa.gov/products/solar-synoptic-map

Tutorial 2 – The Energies of Particles



What is the Purpose of Tutorial 2?

- I will be able to convert numbers to standard form and back
- I will know the main prefixes of the SI system of units
- I will learn how to convert electronvolts to Joules
- I will be able to use the equation $K = mv^2/2$ to convert between speed and kinetic energy and apply this to energetic particles

1. Starter – Describe what a plasma is in your own words

2. Very Big and Very tiny numbers: Standard Form

You may use your calculator for all of these questions. See also the standard form cheat sheet if you are struggling!

<u>Standard Form</u>

Convert the following to standard form.

1. 34800000 = <u>3.48×10^7</u>

2. 54300000000

3. 75400000000000

4. 0.003

5. 0.000000000765

Write out the following numbers in full.

6. 1.23×10^{4} = 12300

7. 5.90×10^{9}

8. 3.08×10^{11}

9. 1.45×10^{-2}

10. 1.60×10^{-19}

Calculate the following sums.

Tip: Type them into your calculator in standard form!

11. $4.97 \times 10^{-6} \times 9.53 \times 10^{8}$

12. $1.01 \times 10^{23} \times 3.56 \times 10^{50}$

13. $9.02 \times 10^{-30} / 8.51 \times 10^{-37}$

14. $4 \times 10^{5} \times 2.5 \times 10^{-6}$

15. $(9.43 \times 10^{8} \times 9.67 \times 10^{3}) / 1.23 \times 10^{-4}$

3. Very big and very tiny units: Prefixes

Convert the following energies to a suitable prefix. See the scientific prefixes sheet if you are struggling!

16. 1.34×10^{9} J = 1.34 GJ

17. 1.6×10^{-19} J

18. 3.2×10^{-17} J

19. 8.76×10^{25} J

20. 3.78×10^{-5} J

Convert these energies back to standard form:

21. 45 GJ = 4.5×10^{10} J

22. 890 EJ

23. 76 mJ

24. 18 yJ

25. 9.23 aJ

K (eV) = 1.6 x10^{-19} x K (J)	Convert from Joules to eV.
$$K = \frac{mv^2}{2}$$	K = Kinetic Energy of particle (J) m = Mass of Particle (kg) v = Speed of Particle (m/s)

Notes for examples and derivations:

Kinetic Energy Example Questions

1. A proton with a mass of 1.67x10^{-27} kg is moving at a speed of 1,000 km/s. Work out the energy of the proton in eV.

First, make sure everything is in the SI base units:

1,000 km/s = 1,000,000 m/s = 1x10^{6} m/s.

Work out the energy in Joules using the formula for kinetic energy:

K_J = 1.67x10^{-27} x $(1{,}000{,}000)^2$ x 0.5 = 8.35x10^{-16} J.

Convert from J to eV:

K_{eV} = 8.35x10^{-16} / 1.6x10^{-19} = <u>5219 eV</u>.

2. An electron has an energy of 6 meV. Its mass is 9.11×10^{-31} kg. Work out how fast it is going.

Convert the energy to the base unit first.

6 meV = 0.006 eV = 6×10^{-3} eV

Now convert the energy from eV to J.

$K_J = 1.6 \times 10^{-19} \times 6 \times 10^{-3} = 9.6 \times 10^{-22}$ J

Now we need to use the kinetic energy formula to find the speed. It is rearranged like this:

$$v = \sqrt{\frac{2K_J}{m}}$$

$V = \sqrt{(2 \times 9.6 \times 10^{-22} / 9.11 \times 10^{-31})} =$ <u>45,900 m/s</u>.

4. The Energy of Plasma Particles

<u>Kinetic Energy Questions:</u>

The mass of a proton is 1.67×10^{-27} kg.

The mass of an electron is 9.11×10^{-31} kg.

The charge on a proton is 1.6×10^{-19} C.

26. A proton is travelling at 1×10^{6} m/s. Work out its kinetic energy in eV.

27. An electron is travelling at 2×10^{4}km/s. Work out its kinetic energy in eV.

28. A proton has an energy of 3 MeV. How fast is it going?

29. An electron has an energy of 12 eV. How fast is it going?

30. A proton has an energy of 1 keV and an electron has an energy of 1 eV. Which of these particles is travelling the fastest?

Bonus: A bullet from an AK47 rifle travels at roughly 740 m/s. Compare the bullet's speed to the proton in question 30. Which is faster and by how much?

Homework 2 – A Day at the Races

(a) A proton challenges an electron to a race. The proton has 10 eV of kinetic energy while the electron has 1 eV of kinetic energy.
Which particle is the quickest? Work out the speeds of each particle.

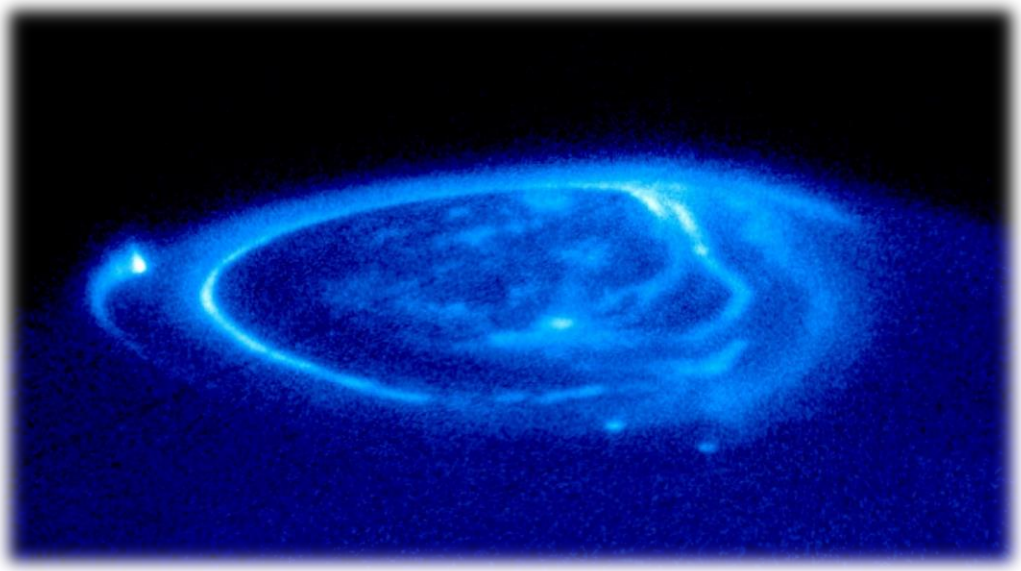
(b) How much energy would the proton need to be travelling at the same speed as the electron? Give your answer in eV.

(c) The equation for the kinetic energy of a particle is:

$$K = \frac{mv^2}{2},$$

where K is the kinetic energy, m is the mass of the particle and v is its speed.
Rearrange this equation to make v the subject of the equation. Explain how you do this.

Tutorial 3 – Making Plasmas

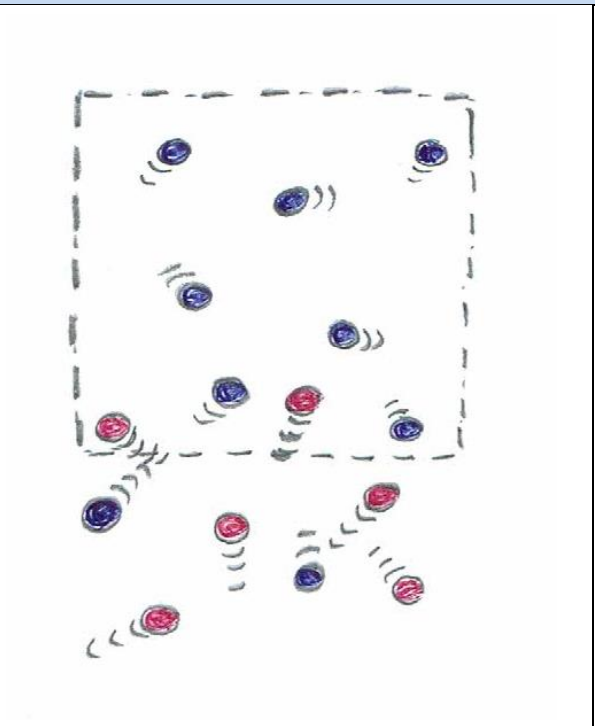


What is the Purpose of Tutorial 3?

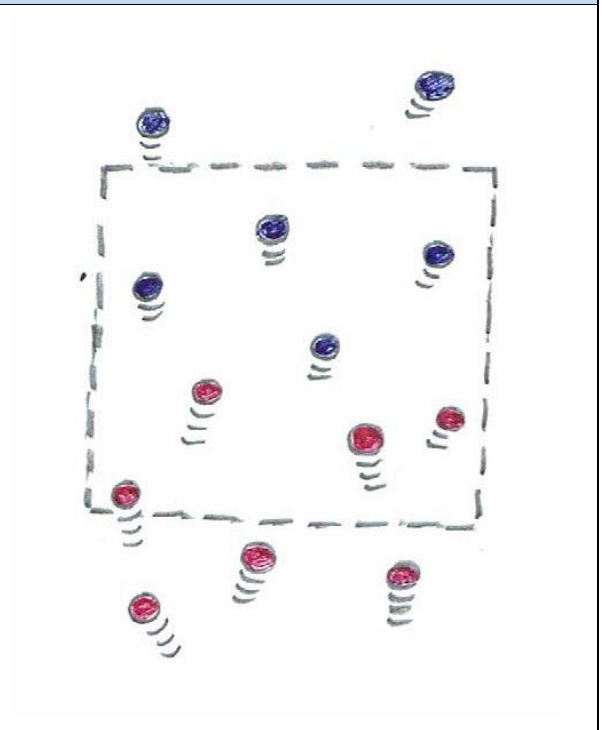
- I will understand the three methods of heating a plasma: conduction, convection, and radiation
- I will understand why we can neglect chemical reactions in plasmas
- I will learn that radiation can refer to electromagnetic waves or energetic particles
- I will understand why a plasma can be collisionless and what this implies

1. Starter – Kinetic Energy
A proton is travelling at 100 km/s. How much kinetic energy has it got in eV?

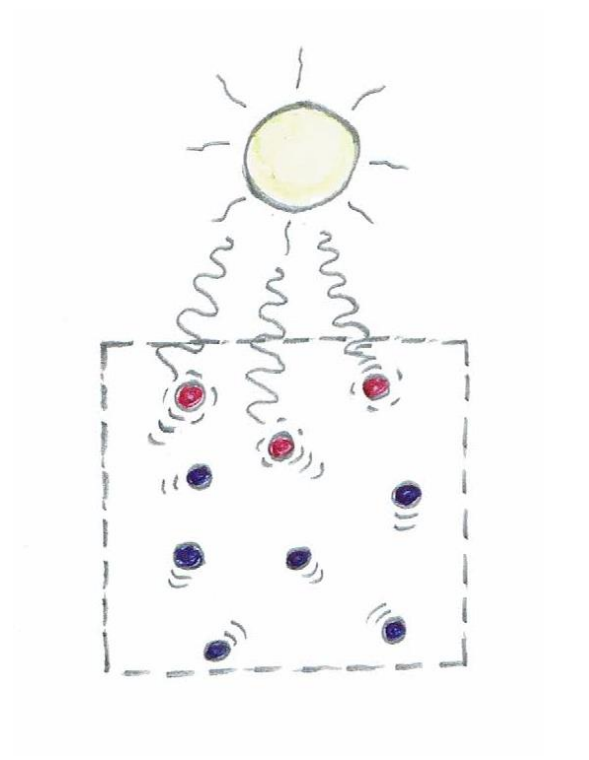
2. Methods of Heating



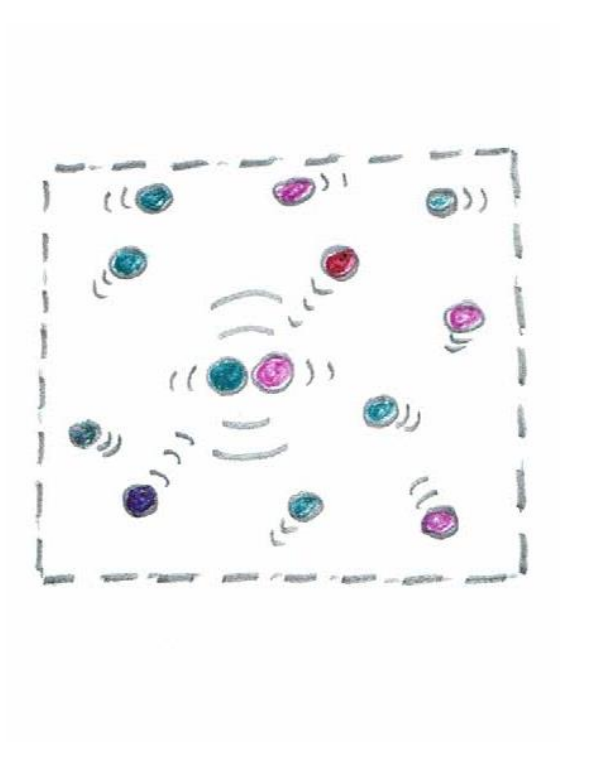
Conduction



Convection



Radiation

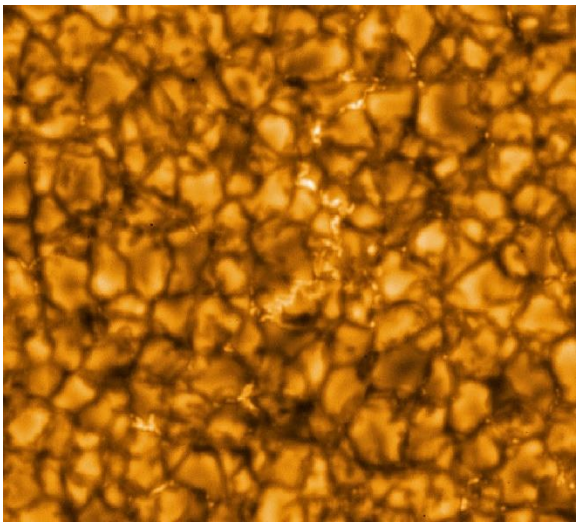


Chemical Reactions

3. What's the Energy Source? – In Pairs

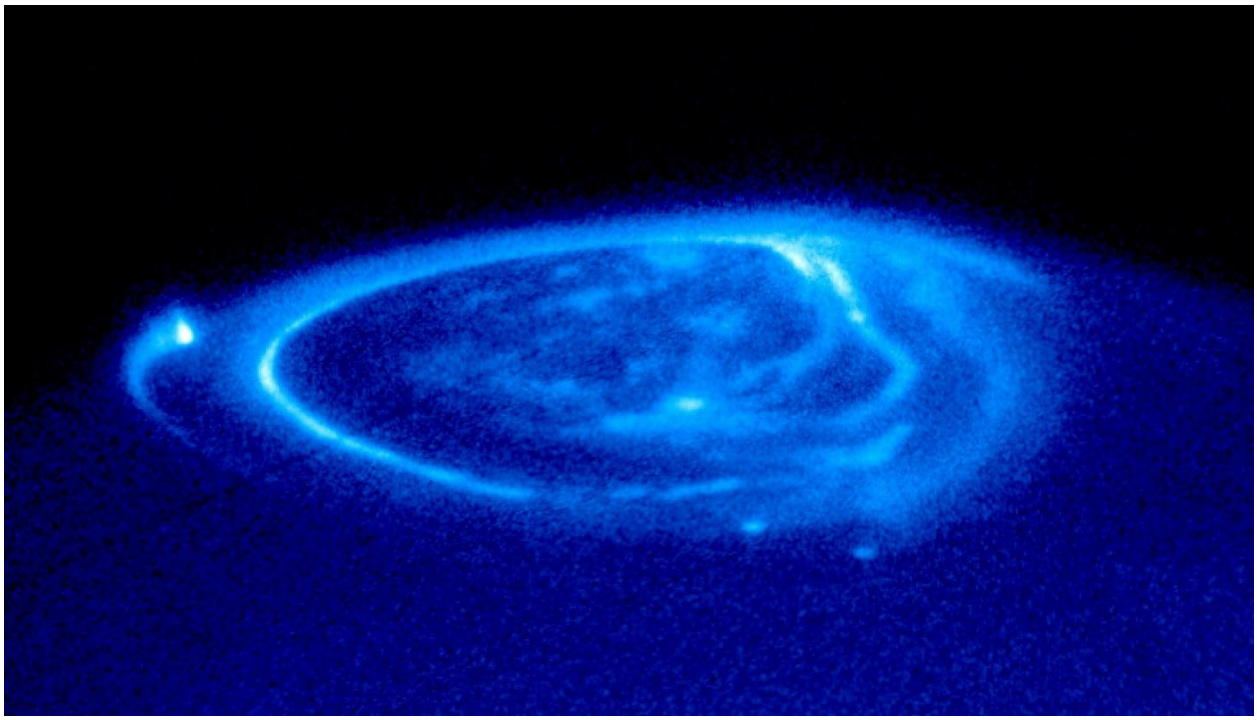
1. Would you expect conduction to be more effective at transferring heat in a solid or a plasma? Why?

2. The image on the right shows plasma on the surface of the sun. Each blob is a convection cell, where plasma rises from underneath the surface. Use your understanding of convection to explain why some bits of the image are brighter than others.



3. The ionosphere is a layer of the Earth's upper atmosphere that is made of plasma. The ionosphere is thicker during the day than at night. How do you think the ionosphere is formed? By what method is it heated?

4. Jupiter's Aurora



This is a Hubble space telescope image of Jupiter's aurora seen in ultraviolet. What do you think is the source of energy needed to make this plasma?

5. Lonely Particles – Collisionless Plasmas

What are the chances of these particles colliding? What does this imply for the transfer of heat in this plasma?

Homework 3 – The Electrolaser

An electrolaser is a weapon that "shoots" electricity at people. Firstly, the weapon fires a laser at the target. This ionises the air molecules between the gun and the target, creating what is called a "laser induced plasma channel". The gun then applies a high voltage to where the laser has just fired, which results in an electric current travelling down the laser beam. This shocks the target.

Use the information above and your knowledge of plasmas to answer the following questions.

a) When the laser is fired, it heats the air in the path of the laser until the air molecules become ionised into plasma. What method of heating is being used here?

b) Air is normally a very good insulator, whereas metals are normally very good conductors because they contain lots of free electrons inside them. Explain why the laser is able to make the air conductive.

c) Can you think of a natural phenomenon on the Earth where electricity can pass through the air in a similar way? Hint – Think bad weather!

d) You have woken up in a James Bond movie and a bad guy is hunting you with his electrolaser. Explain why standing behind a window might keep you safe from him. What could you use in your home to fight back?

Tutorial 4 – Properties of Plasmas

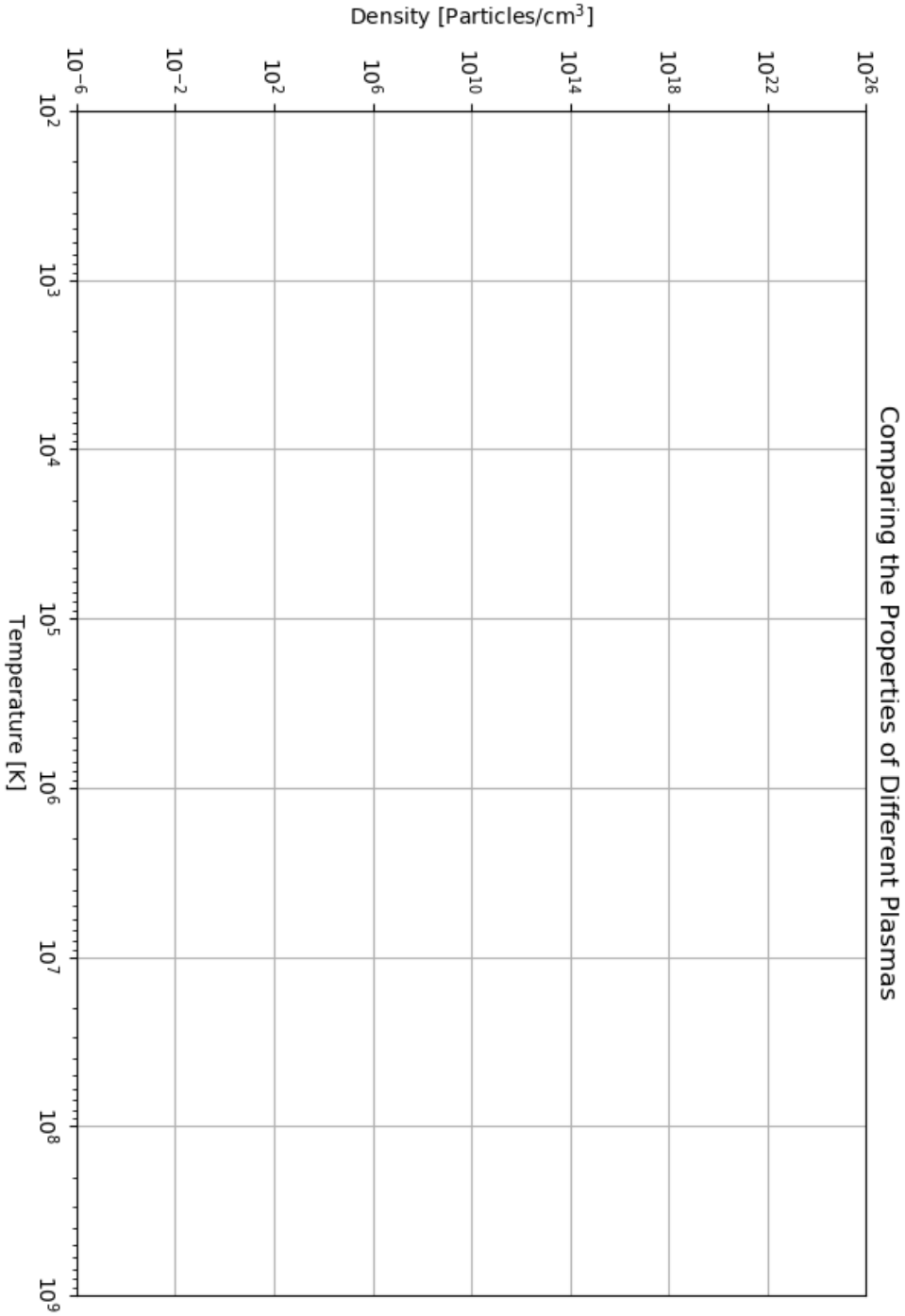
What is the Purpose of Tutorial 4?

- I will be able to define a plasma by its temperature and density
- I will know what quasi-neutrality means
- I will understand why we can neglect electric field effects
- I will be able to reference a book or website

1. Starter – Describe the 3 ways of heating a plasma

1. Density vs Temperature

For this task, you will be given a set of images of different plasmas. You will then put these images on to the diagrams where you think they should go. You can either stick the images on with glue or just write their name. The images are also given to you in the section "Resources for Tutorial 4:"



2. Write down the statements on electric fields

3. The effect of electric fields on plasmas

Explain what you understand about quasi-neutrality. Also explain why we can usually ignore the effect of electric fields on plasmas.

You should draw diagrams to help you.

Homework 4 – Fun Facts

Your task is to find answers to 3 of the questions below about the solar system:

1. What is the surface temperature of the Sun?
2. What is the temperature of Neptune?
3. How many years does it take Jupiter to go around the Sun?
4. When was the probe New Horizons launched to Pluto?
5. What is the main gas on Venus' atmosphere?
6. How close will the Parker solar probe get to the Sun?
7. What is the name of the first animal in space?
8. How many moons does Mars have?

You can choose which three you research and you may use the internet. For each fact, write down the reference of the place you found it in the way we discussed in class. You may also find the information at the end of this workbook helpful.

Here is an example:

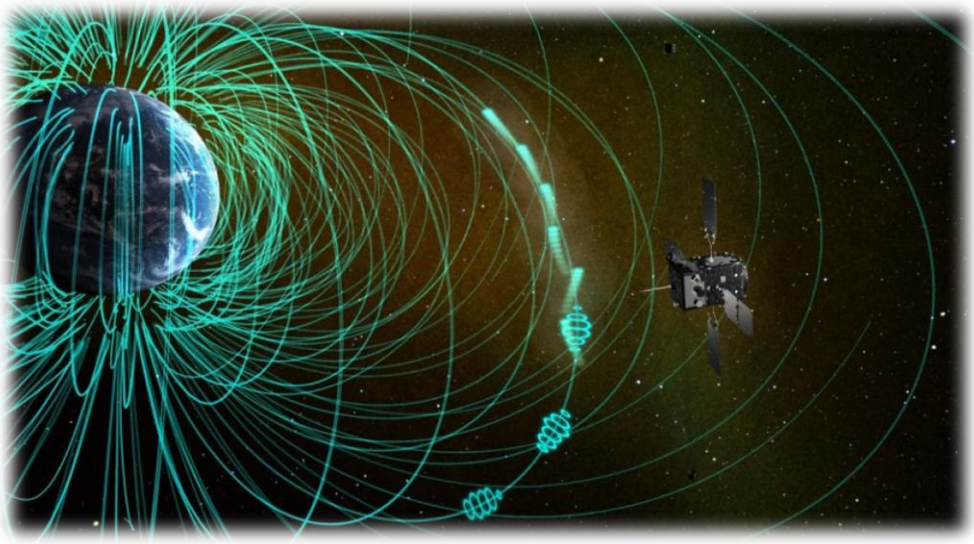
Q: How many moons does Saturn have?

A: Officially, it has 82 moons, but only 53 of them have names so far. The most important are Titan, which is the largest, and Enceladus, which is thought to have liquid water underneath its surface that could support life.

Ref: NASA Solar System Exploration, *Saturn's Moons*, https://solarsystem.nasa.gov/moons/saturn-moons/overview/?page=0&per_page=40&order=name+asc&search=&placeholder=Enter+moon+name&condition_1=38%3Aparent_id&condition_2=moon%3Abody_type%3Ailike&condition_3=moon%3Abody_type , [Accessed: 16/11/2020]

Write your 3 answers and their references in the space below. Alternatively, you may write your answers and references in a word document, print it out and add it to the booklet.

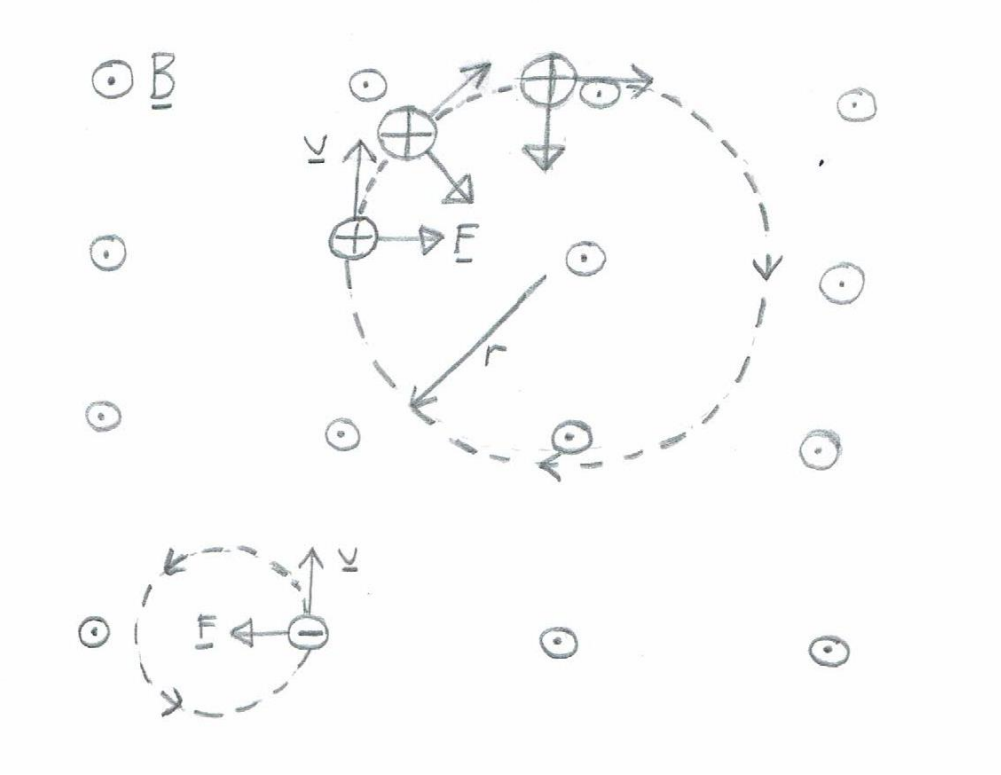
Tutorial 5 – The Interaction with Magnetic Fields



What is the Purpose of Tutorial 5?

- I will understand that magnetic fields cause charged particles to gyrate about the field and be able to use the equation $F = qvB$
- I will know the equation for centripetal force, $F = mv^2/r$, and be able to apply this to magnetic field forces
- I will understand that magnetic fields can trap plasmas and how this is useful
- I will understand what I have to do for my final assignment.

1. Starter – What does quasi-neutrality mean?
Draw a picture to help you explain it.



How a charged particle moves in a magnetic field. The magnetic field, B, points out of the page. The proton will move clockwise and the electron anticlockwise. The proton has a bigger circle because it is more massive.

$$F = Bqv$$ In what directions do these quantities point?	F = Force of the Magnetic Field on the Charged Particle B = Magnetic Field Strength q = Charge on the particle v = Velocity of the Charged Particle

1. Magnetic Fields

1. An electron is travelling in the Earth's magnetic field where the magnetic field strength is 20,000 nT. It has a velocity of 3,000 km/s. What is the size of the force that the electron experiences because of the magnetic field?

2. A proton is travelling through a magnetic field which is pointing out of the page. The proton is moving down the page. Will the proton deflect to the left or the right?

$$F = \frac{mv^2}{r}$$ Can you draw out the diagram for circular motion?	F = Force towards the middle of the circle on the particle m = Mass of the particle v = Velocity of the Charged Particle r = Radius of the Circle

Notes for Derivations:

Example Magnetic Field Question

A proton is travelling at 10,000 m/s in the Earth's magnetic field where the strength is 20,000 nT. What is the radius of the circle that it travels in?

Firstly, identify which equations you will need:

$$F = Bqv = \frac{mv^2}{r}$$

Equate them together to eliminate the force, F, and rearrange for r:

$$r = \frac{mv}{qB}$$

Substitute in your numbers from the question to get the radius. Remember to convert from nT to T!

r = $(1.67 \times 10^{-27} \times 10000)/(1.6 \times 10^{19} \times 20000)$ = <u>5.22 m</u>

2. Going round in circles!

3. For the electron in question 1, what is the radius of the circle that the electron travels in?

4. A proton with a kinetic energy of 1 eV is moving perpendicular to a magnetic field with a strength of 1000 nT. What is the radius of the circle it makes?

5. An electron with a kinetic energy of 1 eV is moving perpendicular in the same field as the proton in question 4. How do you expect the motion of the electron to differ to that of the proton? Hint: Which particle is moving faster?

3. Stretch yourself!

6. The formula for kinetic energy is $K = mv^2/2$. The formula for the radius of gyration is $r = mv/qB$. Show that the radius of gyration can be written in terms of the particle's kinetic energy as:

$$r = \frac{2K}{qvB}$$

7. Dr Wharton wants to trap some plasma in his magnetic bottle so that he can perform some nefarious experiments on it. His magnetic bottle has a diameter of a metre. The protons he injects sideways into his magnetic bottle from his magic proton gun are travelling at 1000 km/s. How strong does the magnetic field have to be to contain his protons inside the bottle?

8. For your particles in questions 3 and 4, how long do they take to go in a complete circle?

Final Assignment

Part 1: The Physics of Plasmas

In this section, you will solve some maths-based problems related to plasmas in the solar system. When using the numbers given, pay attention to the units as they may not always be in standard form! **There are some useful data after the last question that you will find helpful.**

1. The solar wind is a continuous flow of hot plasma originating from the Sun that spreads throughout the solar system. Hydrogen atoms in the solar wind can be ionized by 13.6 eV of energy.

   a) Convert this energy from eV to J

   b) The solar wind escapes the Sun's surface with an average speed of 400 km/s. Assuming it maintains this speed throughout the solar system, work out how long it takes for the solar wind to reach:

   i) Earth
   ii) Jupiter
   iii) The Heliopause (outer boundary of the solar system)

   Give your answer in a sensible unit. You may have to look up the distances of each of the planets from the sun!

   c) In reality, the solar wind will not remain at a constant speed over such distances. Do you expect the solar wind to speed up or slow down as it travels through the solar system? Explain your answer.

2. The Aurora Borealis, or Northern Lights, are created when energetic electrons from outer space collide with atoms in the Earth's upper atmosphere and ionize them by knocking an electron out of its shell. The newly created ions and electrons then recombine to release light.

   To ionize one Oxygen atom requires 2.18×10^{-21} J of energy.
   a) What is the minimum speed needed by an electron to ionize a single Oxygen atom?
   b) If the incoming electron has more energy than this, what might happen to the spare energy?

3. Figure 1 shows some plasma in the ionosphere. The red particles are ions and the blue particles are electrons.

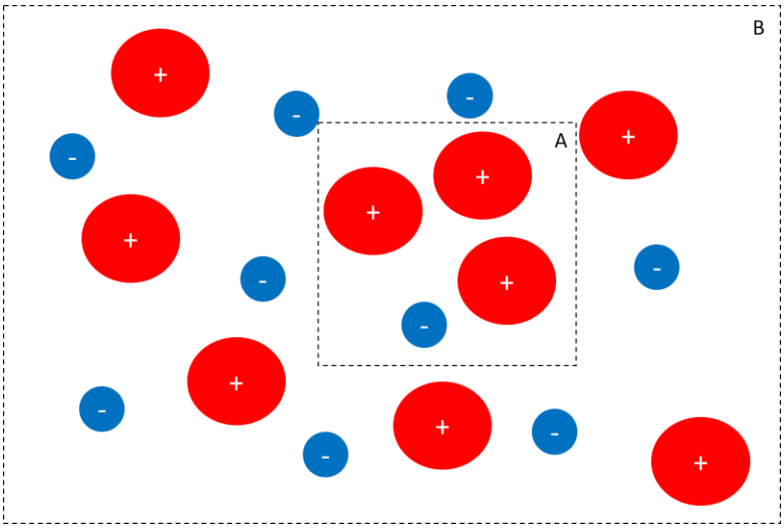


Figure 1:

a) What is the total charge in box A?
b) What is the total charge in box B?
c) What term to do we use to describe the amount of charge in box B?

Figure 2 shows the same plasma immersed in an electric field shown by the green lines.

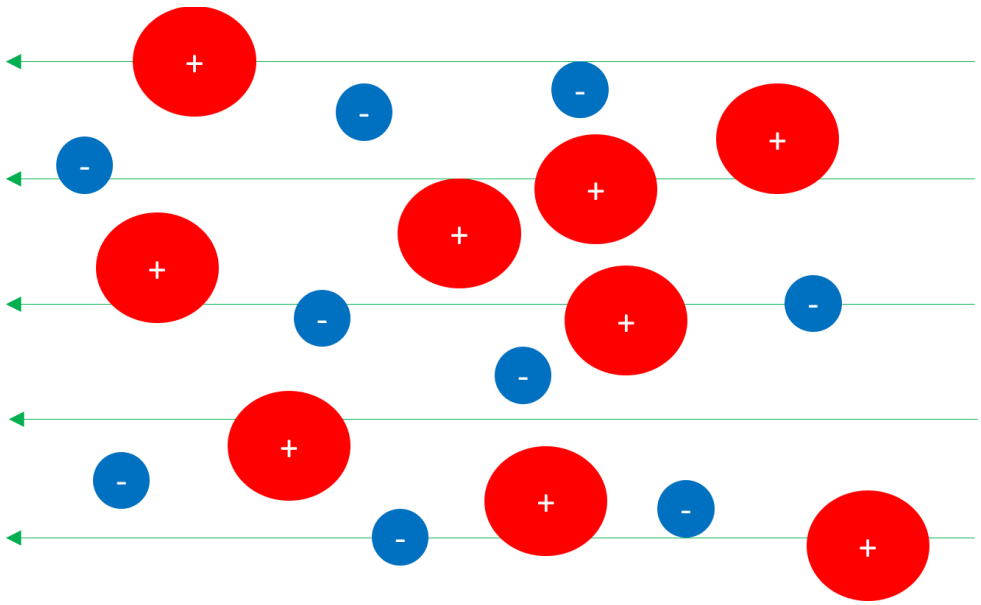


Figure 2:

d) Describe what you think will happen to the particles in this electric field. Consider what directions the particles might move and whether there will be any changes in the forces involved.

e) At the top of the ionosphere, the density of plasma is low enough we can consider the plasma to be collisionless. Lower down in the atmosphere, the particles will regularly collide. Discuss how your answer for part d changes for these two scenarios.

4. An electron is trapped in the outer radiation belt of the Earth's magnetosphere where the magnetic field strength is 111 nT. It has an energy of 10,000 keV.

a) Calculate the speed of the electron in km/s.
b) How many times faster is the electron than a bullet from an AK47 rifle? Give a reference for where you obtained the speed of the bullet.
c) NASA is operating a weather satellite where these electrons reside. What advice would you give NASA with regards to these energetic electrons?
d) The electron will experience a force from the Earth's magnetic field that causes the electron to move in a circle. Explain how the magnetic field causes the electron to move in a circle.
e) What is the radius of this circle?

Useful Data for Part 1:

Mass of an electron = 9.11×10^{-31} kg
Charge of an electron = -1.6×10^{-19} C
Astronomical unit = 1.49×10^{11} m

Part 2: My Favourite Plasma

In this part, you will do a small piece of independent research about a plasma in the solar system. Ensure that you keep track of where you get your information from so that you can put references in your essay. It is strongly encouraged you include any awesome facts and pictures that you come across!

Choose a plasma from the following list:

- Earth's radiation belts
- Earth's ionosphere
- The Solar Wind
- Comet's Tail
- The Earth's magnetosphere
- Jupiter's magnetosphere
- The Auroral Zone

Conduct some research on your chosen plasma and write an essay of approximately 1000 words. You might find I helpful to answer the following questions in your essay:

1. Where is this plasma? What is it?
2. What are the plasma's properties? (temperature, density, degree of ionization and composition) How much energy do its particles have?
3. How was it discovered?
4. Can you explain how it is created?
5. Does it have any cool features?
6. Do magnetic fields have an effect on it? Can you explain this?
7. Are there any outstanding mysteries about the plasma?
8. How are we investigating this plasma to try and solve these mysteries?

Success Criteria:

Part 1:

Understand	Be able to do
Which equation to apply for the appropriate problem	Use simple equations correctly
Plasmas can be created by interaction with energetic photons and electrons as well as heating	Convert units when necessary

The solar wind is a plasma that travels through the whole solar system	Display full working
Understand that a charged particle in a magnetic field will move in a circle	Apply some physical understanding to predict the outcome of a given scenario
Understand how electric fields affect plasmas	Explain the physics of a given scenario

Part 2:

Understand	Be able to do
There are many different plasma populations in the solar system with very different properties	Find information independently
Everything we know about these plasmas comes from measurements	Referencing literature
These plasmas are created in different ways	Organise information into a sensible order
There are still outstanding mysteries about these plasmas	Use scientific language correctly

Tutorial 6 – Feedback tutorial

What is the Purpose of Tutorial 6?

- To receive feedback on your final assignment
- To respond to the feedback from your Uni Pathways teacher
- To write targets for improvement on your final assignment

Final assignment feedback from your Uni Pathways Teacher

(Remember to look at the mark scheme to help you understand what you have done well so far, and how you can do even better in your final assignment)

Here are three things that my Uni Pathways Teacher thought I did well in my draft assignment
•   •   •

Here are three things that my Uni Pathways Teacher thinks that I could do to get a higher mark in my final assignment
•   •

•

Tasks from my Uni Pathways Teacher to do during the feedback tutorial to help me improve
•   •   •
My response:

Actions I will take to improve my final assignment after this tutorial…
•   •   •

Hand in date for my final assignment:	

Tutorial 7 – Final tutorial

What is the Purpose of Tutorial 7**?**

- To receive feedback and a grade on your final assignment.
- To reflect on the programme including what you enjoyed and what was challenging.
- To ask any questions you may have about university.

Final assignment feedback from my Uni Pathways Teacher

Final mark:	University style grade:
Feedback: Here are three things that my Uni Pathways teacher thought I did well in my final assignment • • •	

Here are three things that my Uni Pathways teacher thinks I should remember for when I am doing this kind of study in the future
• • •

University

What questions do you still have about University after taking part in Uni Pathways?
•   •   •

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.

Standard Form Cheat Sheet

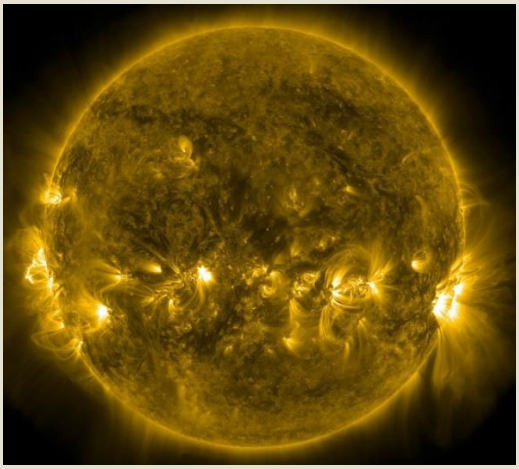
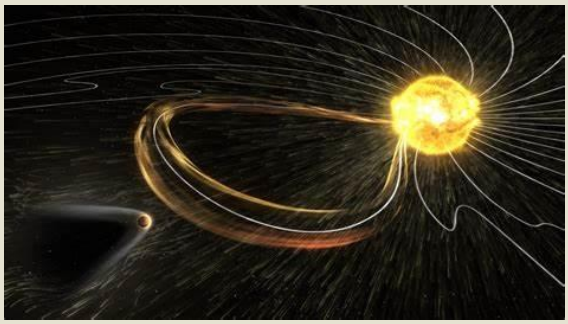
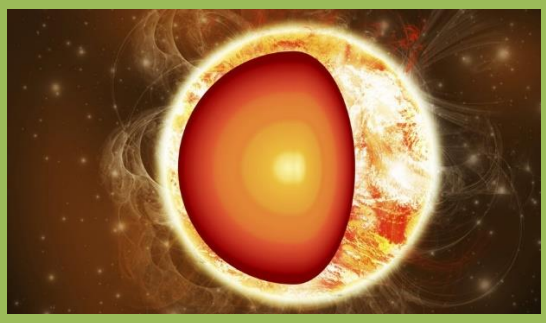
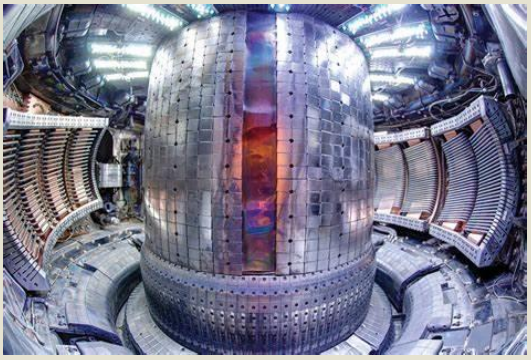
In Standard Form	Written in Full
10^{-5}	0.00001
10^{-4}	0.0001
10^{-3}	0.001
10^{-2}	0.01
10^{-1}	0.1
10^{0}	1
10^{1}	10
10^{2}	100
10^{3}	1000
10^{4}	10000
10^{5}	100000

Scientific Prefixes

Prefix	Symbol	Standard Form	Number's Name
Yocto	y	10^{-24}	Septillionth
Zepto	z	10^{-21}	Sextillionth
Atto	a	10^{-18}	Quintillionth
Femto	f	10^{-15}	Quadrillionth
Pico	p	10^{-12}	Trillionth
Nano	n	10^{-9}	Billionth
Micro	µ	10^{-6}	Millionth
Milli	m	10^{-3}	Thousandth
-		10^{0}	One
Kilo	k	10^{3}	Thousand
Mega	M	10^{6}	Million
Giga	G	10^{9}	Billion
Tera	T	10^{12}	Trillion
Peta	P	10^{15}	Quadrillion
Exa	E	10^{18}	Quintillion
Zeta	Z	10^{21}	Sextillion
Yotta	Y	10^{24}	Septillion

Resources for Tutorial 4:

Aurora	Comet
Fire	Laser
Lightning	Nebula

	
Fluorescent Lights	Sun's Surface
	
Solar Corona	Solar Wind
	
Sun's Core	Fusion Reactor

Notes

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researchersinschools.org