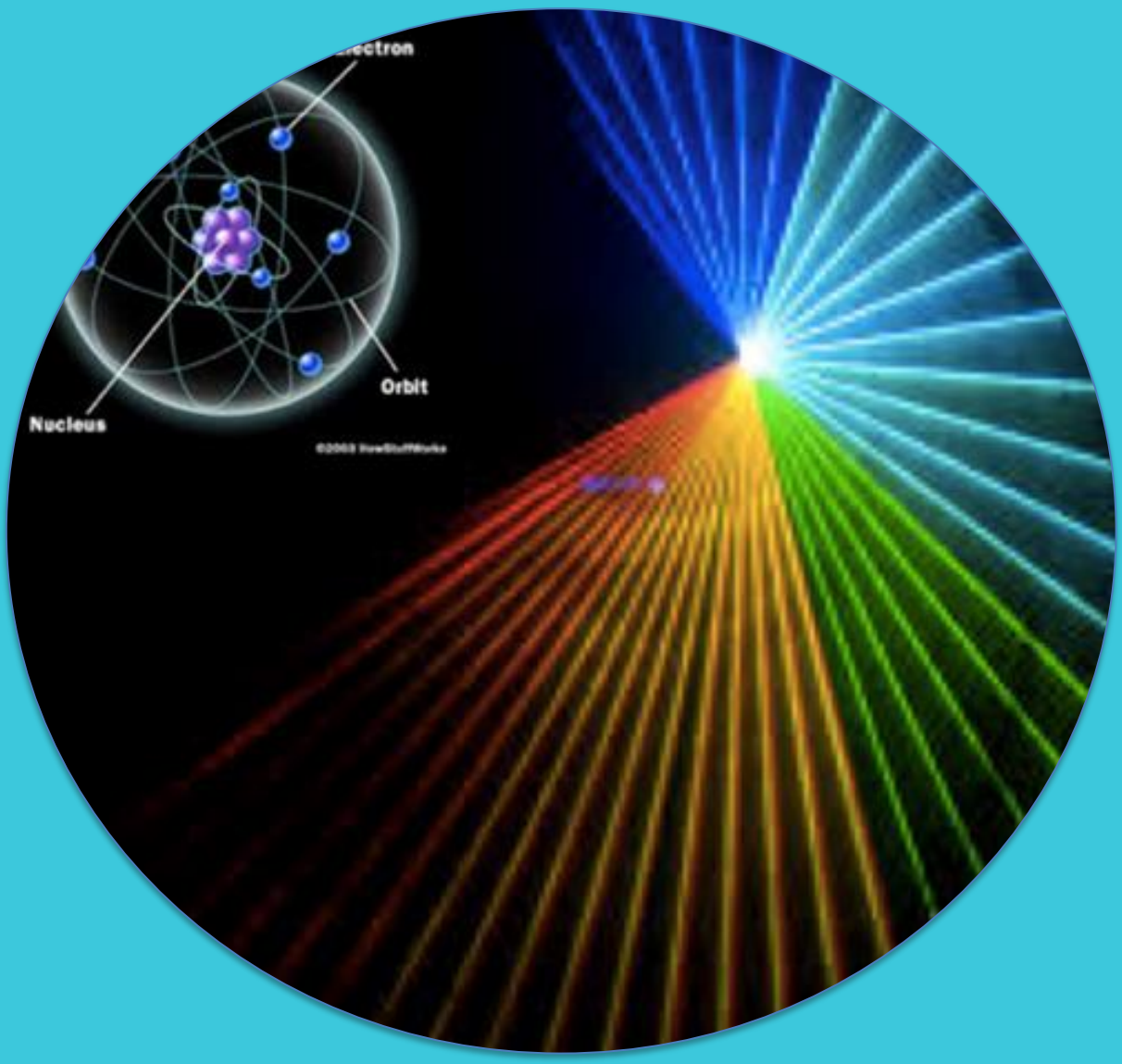
Researchers in Schools



From Atoms to Laser, what is the Connection?

Key Stage 3 Programme

Pupil Name	
Coursebook Designed by	Dr M H Abdalmoneam

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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	Assignment 2: waves	
Tutorial 3	Assignment 3: Atomic models	
Tutorial 4	Assignment 4: Spectrum of Hydrogen atom	
Tutorial 5	Final Assignment: Atomic physics and its applications	
Final Assignment		

Assignment Submission – Lateness and Plagiarism

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

Course Rationale

Have you ever questioned about the building units of the stars, the plants, the animals, and your own body? You may know these are all atoms. But do you know that inside each tiny atom thousands of interactions may be happening every second? Do you know that when we dive deep in the atom, we rediscover the nature? Do you know that when we dive even deeper in the atom we come up with a new invention? These inventions change the shape and quality of our life.

This course takes you on a journey that starts with the discovery of the basic components in the atom. A discovery that marked the birth of Atomic Physics. You will see and practise how our understanding of the components and interactions inside the atoms have developed through many experiments. You will learn how atoms can produce light. Such an astonishing discovery, that the light made by the sun and the stars is actually produced by their atoms! Then you will learn about laser light, an amazing invention that crowned our scientific efforts in learning about what is inside atoms. Thus, the objectives of this course are to learn about the atomic structure, and the electronic transitions, to calculate the energy and wavelength of the emitted photons, to explain the general work principle of laser, and to discuss how laser light is produced based on the principles of atomic physics.

From Atoms to Laser, what is the Connection? is a course that speaks to the scientist inside you. It invites you to act as a scientist. You will observe, record data, question, investigate, think, make conclusion, and write as a scientist. You will live and express your scientific identity. Your experience in this course will assist you to know and appreciate how important science is in improving our life. Also, you will see what is waiting for you if you choose to study physics at A level and at university. And, hopefully, you will be able to make educated decisions for your future studies and career.

Uni Pathways Mark Scheme 2020 – science-based assignment

	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 (essay based): Pupil Feedback Report

Name of Pupil	
Name of School	
Name of RIS teacher	
Title of Assignment	

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

Final Assignment (essay based): Pupil Feedback Report

Name of Pupil	
Name of School	
Name of RIS teacher	
Title of Assignment	

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

Subject Vocabulary

Word	Definition	In a sentence
Atom	The smallest unit of matter which contains a collection of electrically positively charged, negatively charged, and neutral particles.	The periodic table provides the names of all the atoms that we know.
Atomic Physics	The branch of science that studies the components of the atoms with main focus on the electrons and their interactions inside the atom.	At university, if you choose to study atomic physics, you can learn about the energies and interactions inside the atoms.
Scattering	The process in which a particle or a beam of particles are deflected from their original trajectory because of approaching a charged particle or entering an electromagnetic field.	When a stream of protons approaches a positively charged point, they scatter away from it.
Frequency	The number of repetitions of a specific event per unit time; SI: (Hz) or in inverse-second (s^{-1}).	If your grandfather has a clock that ticks twice within a second. This means that It ticks with a frequency of 2 Hz.
Wave	A model that physicists use to describe the continuous spread of energy either in vacuum or in matter.	Light and sound are examples of waves.
Wave frequency	the number of waves that passes a specific point per unit time; SI: Hertz (Hz) or in inverse-second (s^{-1}).	If there are five new waves of sound created every second, this means a frequency of 5 Hz.
Wavelength	The distance between two similar points (e.g. crests or troughs) on the path of a wave. It is measured in unites of length; SI: metre (m).	The distance between two successive crests of water waves is 2 meters, i.e. the wavelength is 2 m.
Neutron	A neutral particle that is usually found in the atomic nucleus.	Neutrons have zero electric charge.
Proton	A positively charged particle that is usually found in the atomic nucleus.	Protons repel each other because they have positive electric charge.
Spontaneous emission		
Stimulated emission		

Tutorial 1 – Matter Versus Waves

Prior knowledge

- The basic components of the atom (neutrons, protons, and electrons)
- The "2, 8, 8" pattern of the electron distribution

What is the Purpose of Tutorial 1?

- To experience the experimental design that was used to discover the structure of the atom (30-40 min)
- To investigate the relation between speed, wavelength and frequency of waves (20 min)

Introduction

For a long time, scientists treated matter and light in completely different ways. Matter was thought to be made up small particles, but they did not know what these particles looked like. While light was considered to be a form of continues waves that carry energy. That was in classical physics.

Modern physics started by conducting experiments to learn about the details of the small particles of matter. Later, they found that light and all electromagnetic waves can be represented as streams of particles. This marked an essential link between matter and waves.

In the first part of this tutorial, we will discuss some of the early experiments that l guided our modern understanding of the atoms. Then we will learn about the waves.

Activity 1: Background of Rutherford Scattering experiment:

Rutherford Scattering Experiment

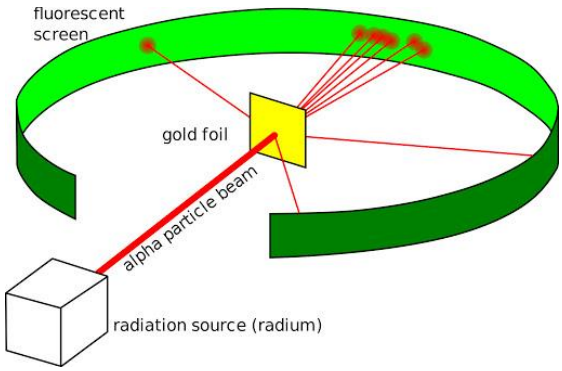


Figure 1: A diagram of Rutherford scattering experiment.
Source: http://large.stanford.edu/courses/2017/ph241/sivulka2/

Answer the following

a) What did Rutherford know before conducting his scattering experiment?

b) What was the goal of his experiment?

c) Explain the scientific principle that Rutherford used to design his scattering experiment.

Activity 2: Computer Simulation

https://phet.colorado.edu/en/simulation/rutherford-scattering

Aim

- To investigate the behaviour of alpha particles when they encounter the nucleus of gold atoms.

Notes and Instructions:

- The Plum Pudding Atom is what Rutherford expected to see
- If the simulation does not work on the website, download the file and play it on the computer.
- You may need to pause the simulation and use the step forward button to monitor the motion more closely.

Investigations

- **First Investigation: Choose the plum atom model**
  In this model, the red represents the positive charge while the blue represents the electrons.
  a) How are the positive and negative charge distributed in the plum pudding atom?

  b) Describe the trajectory of the alpha particles as they pass through the plum atom.

  c) Why did Rutherford predict that alpha particles will pass straight through the gold foil?

  d) In the actual experiment, did the alpha particles have a straight path?

- **Second Investigation: Choose the Atomic view**
  a) How do alpha particles move near the nuclei?

  b) How do alpha particles move near the electrons?

  c) Explain why they move this way.

- **Third Investigation: Choose the nuclear view**
  a) Turn on the alpha particles source.

  b) Describe the motion of alpha particles as they pass through the gold foil.

c) Why do alpha particles deflect?

d) Change these parameters one at a time and observe which of them impacts the alpha particles movement. Write your comment on each change.

Variable	Comment
Energy of alpha particles	
Number of Protons	
Number of neutrons	
Number of neutrons	

- **Conclusions of Rutherford Scattering experiment**

Do your observations support the plum model?

What did Rutherford conclude from this experiment? How did he reach this conclusion?

Activity 3: B-Waves

Waves represent the continuous spread of energy. Waves can spread in media, e.g. sound and water waves. They can also spread in vacuum, e.g. light, radio waves, and all electromagnetic waves.

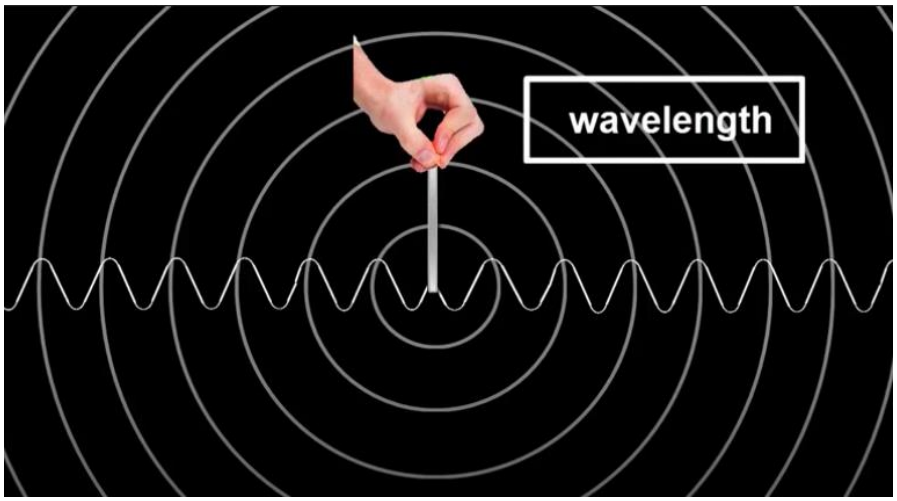


Figure 2: A diagram of water waves.
Source: https://www.youtube.com/watch?v=KWzyQKcJBYg

1. Give three examples of Waves

2. How are waves different from particles?

3. How would you describe a wave to a friend?

Watch this video:
https://www.youtube.com/watch?v=KWzyQKcJBYg
Draw and describe a wave in the space below.

4. All waves share the following properties:
   - They are continuous;
   - They carry energy;
   - They have speed, wavelength and frequency.

Speed = wavelength x frequency

$$v = \lambda f$$

5. A water wave has a speed of 2 m/s and frequency of 20 Hz. What is its wavelength?

6. A sound wave has a speed of 344 m/s and wavelength of 0.2 m. What is its frequency?

Baseline Assignment

1) What was the importance of the Rutherford Scattering experiment?

2) Was Rutherford able to see the atoms? If yes, what did he see? If no, how did he learn about the structure of the atom?

3) Explain the following terms:

a) Alpha particles are .....

b) Scattering means .....

c) Wavelength of a wave .....

d) Frequency of a wave .....

e) Speed of a wave.....

Tutorial 2 – Matter versus Waves-2

What is the Purpose of Tutorial 2?

- When given the energy of an electromagnetic wave, I can calculate its wavelength and frequency
- When given the energy or wavelength of an electromagnetic wave, I can determine its class

Activity 1: Electromagnetic Waves

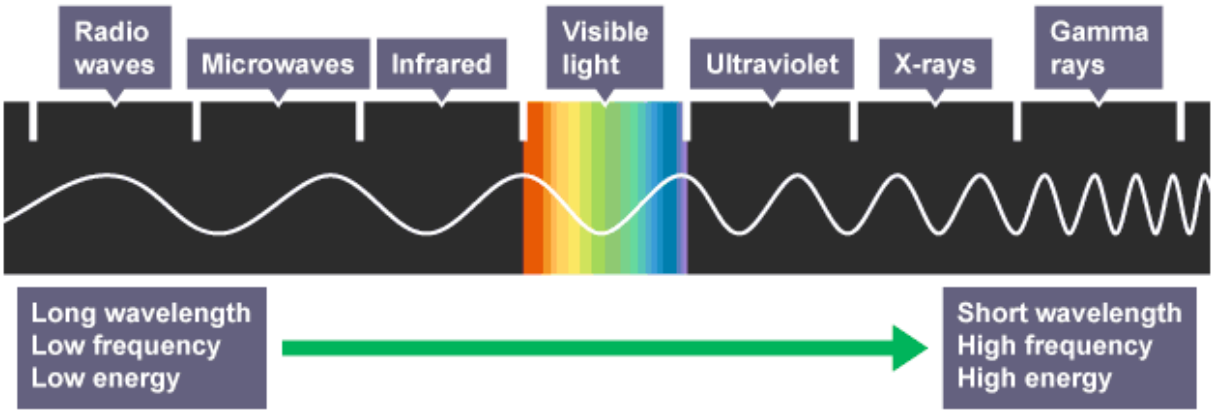


Figure 3: Types of electromagnetic waves. Source: https://www.bbc.co.uk/bitesize/guides/z32f4qt/revision/1

Properties of Electromagnetic waves:

- They travel in vacuum
- They have constant speed in vacuum, c= 3 x 10^8 m/s.
- They are made of small particles, called photons.
- Photons carry energy

Energy of a photon = A constant value (h) x wave's frequency

$$E = h f$$

$$E = h \frac{c}{\lambda}$$

Plank's constant (h) = 4.1357 × 10^{-15} eV s

1. How long does it take the light to travel from the sun to earth (distance=149 million km)?
Choose: 8 min 8 hours 80 min 8 seconds

2. What is the frequency of ultraviolet waves that have energy 12.4 eV?

3. What is the wavelength of the same waves?

4. Colour of Electromagnetic waves

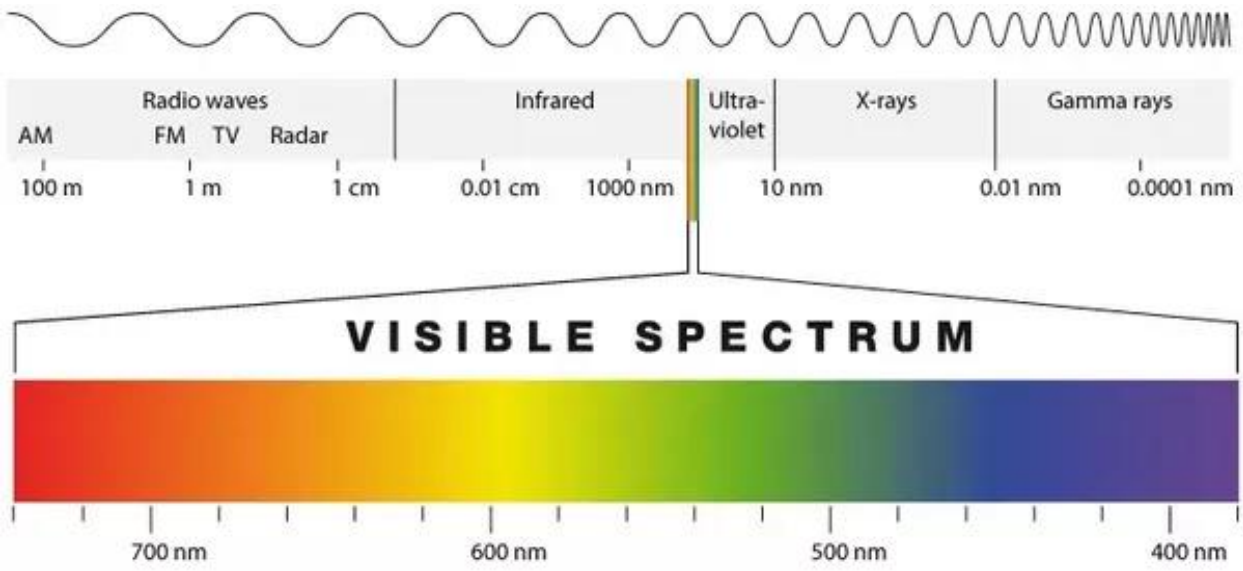


Figure 4: Wavelengths of electromagnetic waves. Source: https://www.quora.com/How-are-electromagnetic-spectrum-and-electromagnetic-waves-related.

- On Figure 4, draw an arrow for each of the following:

  a) the direction of wavelength increasing (below the figure)

  b) the direction of frequency increasing (above the figure)

  c) the direction of energy increasing (above the figure)

- Use figure 4 and the electromagnetic wave energy equation to complete the table

Colour of light	Wavelength	Energy
Purple		
Green		
Yellow		
	650 nm	
	750 nm	

Homework: Waves

1. Arrange the electromagnetic waves according to their energies from smallest to biggest:

X ray Radio waves, Ultraviolet, Visible light, Infrared Gamma rays

2. Which of these waves are most dangerous to health? Why?

3. Compare and contrast between the classical view and the modern view of waves.

4. What are the units of: wave speed, frequency, and wavelength?

5. Write the value and unit of Plank's constant.

6. Calculate the average frequency of a green light.

7. Calculate the average energy of a blue light.

8. What is a photon?

Tutorial 3 – Exploring the Atomic Models

What is the Purpose of Tutorial 3?

- I can summarise the main features of the proposed atomic models
- I can xplain why some models were rejected and other were accepted

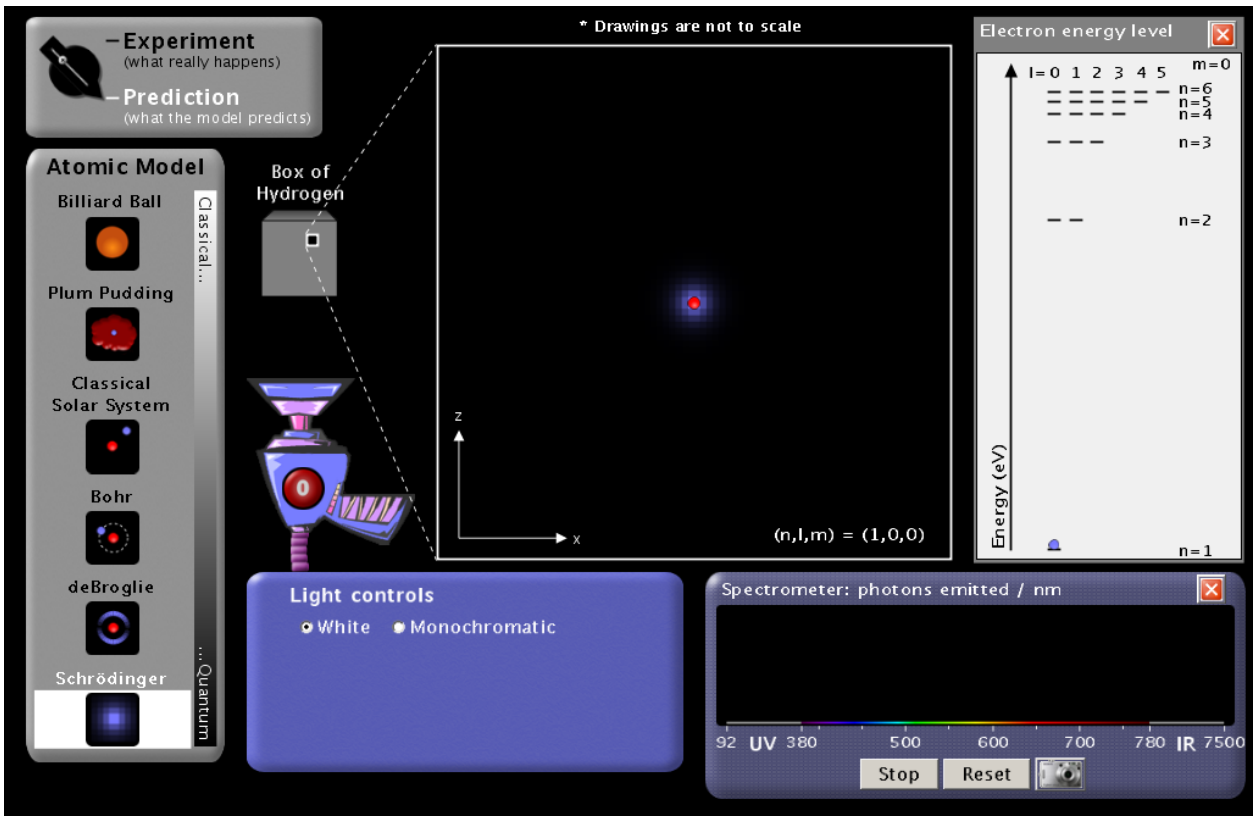
PhET Simulation
Exploration – Models Hydrogen Atom*
*By: Trish Loeblein patricia.loeblein@colorado.edu
http://phet.colorado.edu/simulations/sims.php?sim=Models_of_the_Hydrogen_Atom

Overview

One of the most tantalizing puzzles at the beginning of the 1900s for scientists was to describe the make-up of the atom. Experimentally, light was used to investigate the make-up of the atom.

In this activity, you will first observe a simulated light spectrum of hydrogen gas. You will then look at spectra predicted by different models of the atom. This includes:

- John Dalton's *Billiard Ball* model
- J.J. Thomson's *Plum Pudding* model
- Ernest Rutherford's *Classical Solar System* model
- Niels Bohr's *Shell* model
- Louis deBroglie's *Electron Wave* model
- Erwin Schrodinger's *Quantum Mechanical* model



Procedure and questions

1. Access the **PhET** website.

2. Search for **Models of the Hydrogen Atom** and run it.

3. Click on the *Expand* box in the top right corner of the simulation so that the simulation completely fills the screen.

4. Turn on the White light gun. The white light is shining into a transparent box containing hydrogen gas molecules.
    - **Explain why, with white light, the light photons passing up through the box have different colors.**

5. Check the **Show Spectrometer** box. Notice that the color of the photons passing up through the box corresponds to a wavelength of UV, visible, or IR radiation.

6. In the **Light Controls**, click on *Monochromatic*. Notice that the incoming photons are now all the same color. A spectrum slider appears that allows you to change the energy of the incoming photons. Move the slider across the spectrum from ultraviolet (UV) down to the infra-red (IR). Notice the color of the lamp and the photons moving up the screen. Decide how you can distinguish between UV and IR photons. Record that information below.

7. Switch the **Light Controls** back to *White* light
8. Move the *Slow…Fast* slider all the way over to *Slow*
9. Watch the photons carefully. Most of the light gun photons pass through the box of hydrogen unaffected. Occasionally a photon is absorbed by something in the box and a new photon of the same energy (colour) leaves the box.
    - Describe what is going on in the box.

10. Move the *Slow…Fast* slider all the way over to *Fast*, **Reset** the **Spectrometer**, and let the simulation run for 1 minutes.
11. After 1 minutes, click on the **Spectrometer** camera to take a snapshot of the **Experiment**.
12. Describe what is happening to the spectrum below. Include in your description the *colors*, estimated *wavelengths*, and *relative numbers* of stacked colored balls. These colored balls correspond to photons emitted by the box.

13. Slide the snapshot off to the right of the screen for later comparison with the models.
14. Close the **Show Spectrometer** box
15. Remember that John Dalton proposed that an atom was simply a very tiny hard ball. To see this simulated, in the top left corner, switch from **Experiment** to **Predict** and highlight the **Billiard Ball** model.
16. Move the *Slow…Fast* slider all the way over to *Slow* and describe what is happening below.

17. Below, sketch your idea of what the spectrum will look like for Dalton's model.

18. Move the *Slow…Fast* slider all the way over to *Fast*, reset the **Spectrometer**, and let the simulation run for 1 minutes.
19. Click on the **Spectrometer** camera to take a snapshot of the **Billiard Ball**. Compare it to the **Experiment**. Slide these snapshots off to the right for later comparisons.
    - Does the spectrum for the **Billiard Ball** model match that of the experimental (real) hydrogen spectrum?

20. Switch to Thomson's **Plum Pudding** model, close **Show Spectrometer**, and move the *Slow…Fast* slider all the way over to *Slow*. (your snapshot will disappear as well. Don't worry, it will come back when you open **Show Spectrometer** again). Describe what is happening within the atom below.

21. Move the *Slow…Fast* slider all the way over to *Fast*, reset the **Spectrometer**, and let the simulation run for 1 minutes.
22. Click on the **Spectrometer** camera to take a snapshot of the **Plum Pudding** model. Compare it to the **Experiment**. Slide the snapshot off to the right for later comparisons.
    - Does the spectrum for the **Plum Pudding** model match that of the real hydrogen spectrum?

23. Just for fun, switch to the **Classical Solar System** model. This was Rutherford's model that assumes the atom is like our solar system. Describe what happens below.

24. Switch to the **Bohr** model, click on **Show electron energy level** in the upper right hand corner, and set the speed to *Slow*.
    - *NOTE: These three next steps are critical to you understanding the Bohr atom model*
    - Describe what you see in the atom diagram.
    - Describe what you see in the energy level diagram
    - Describe how the atom diagram and energy level diagrams are related.

25. Move the *Slow…Fast* slider all the way over to *Fast*, reset the **Spectrometer**, and let the simulation run for 1 minutes.
26. Click on the **Spectrometer** camera to take a snapshot of the **Bohr** model. Compare it to the **Experiment**. Slide the snapshot off to the right for later comparisons.
    - How well does the **Bohr** Shell model spectrum match the experimental (real) hydrogen spectrum? *Explain in detail.*

27. *In the **Bohr** Shell model, electrons can exist only at certain energy levels (also called shells), not at any energy levels between them. Shells in this energy diagram go from 1 to 6. An increase in energy level (say from 1 → 6) can only occur if a photon of incoming light is absorbed. A decrease in energy level (say from 2 →1) is accompanied by the emission of a photon as the excited electron releases its excess energy*.

28. In the *Help* menu, select *Transitions* to see all possible transitions.

29. Move the *Slow…Fast* slider all the way over to *Slow*

30. Set the **Light Controls** to **Monochromatic**.

31. Set the monochromatic light source to 122 nm by clicking on the slider box and type in "122." This provides photons of just the right energy to raise (excite) the electron from n=1 to n=2 shell (1→ 2 transition). Describe the atom diagram and the energy level diagrams. Notice that the electron decays are colored. What is the meaning of the colors?

32. Set the light source to 103 nm. This provides photons of just the right energy to raise (excite) the electron from n=1 to n=3 shell (1→ 3 transition). Describe the atom diagram and the energy level diagrams. How do the transitions differ from 1→2?

33. Just to make sure you understand this model, set the light source to 97 nm. This provides photons of just the right energy to raise (excite) the electron from n=1 to n=4 shell (1→ 4 transition). Describe the atom diagram and the energy level diagrams. How do the transitions differ from 1→2 and 1→3 ?

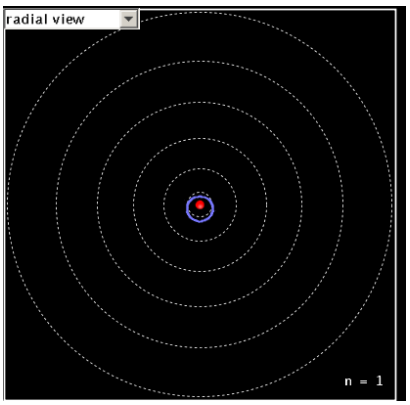
34. Set the light source to 656 nm. This corresponds to a transition from 2→3. What happens? *Explain*.

Luis de Broglie was the first atomic theorist to incorporate the ideas of Planck and Einstein that electrons can be both waves and particles. He developed the de Broglie hypothesis stating that any moving particle or object had an associated wave (wave-particle duality). De Broglie thus created a new field in physics called wave mechanics, uniting the physics of light and matter. For this he won the Nobel Prize in Physics in 1929. Among the applications of this work has been the development of electron microscopes.

35. Set the **Light Controls** back to **White**. Switch to the **de Broglie** Electron Wave model. Describe what is the same and different about the de Broglie and Bohr models of the hydrogen atom.

36. Move the *Slow…Fast* slider all the way over to *Fast*, reset the **Spectrometer**, set **Light Controls** to **White**, and let the simulation run for 1 minutes.
37. Click on the **Spectrometer** camera to take a snapshot of the **de Broglie** model. Compare it to the **Experiment**. Slide the snapshot off to the right for later comparison with other models.
    - How well does the **de Broglie** Electron Wave model spectrum match the real hydrogen spectrum?

38. In the top left corner of the atomic view, change the *radial view* to *3-D view*. Describe what you see.



Erwin Schrödinger began thinking about wave mechanics in 1925. His interest was sparked by a footnote in a paper by Albert Einstein. Like de Broglie, he began to think about explaining the movement of an electron in an atom as a wave. By 1926 he published his work, providing a theoretical basis for the atomic model that Niels Bohr had proposed based on laboratory evidence. The equation at the heart of his publication became known as Schrödinger's wave equation.

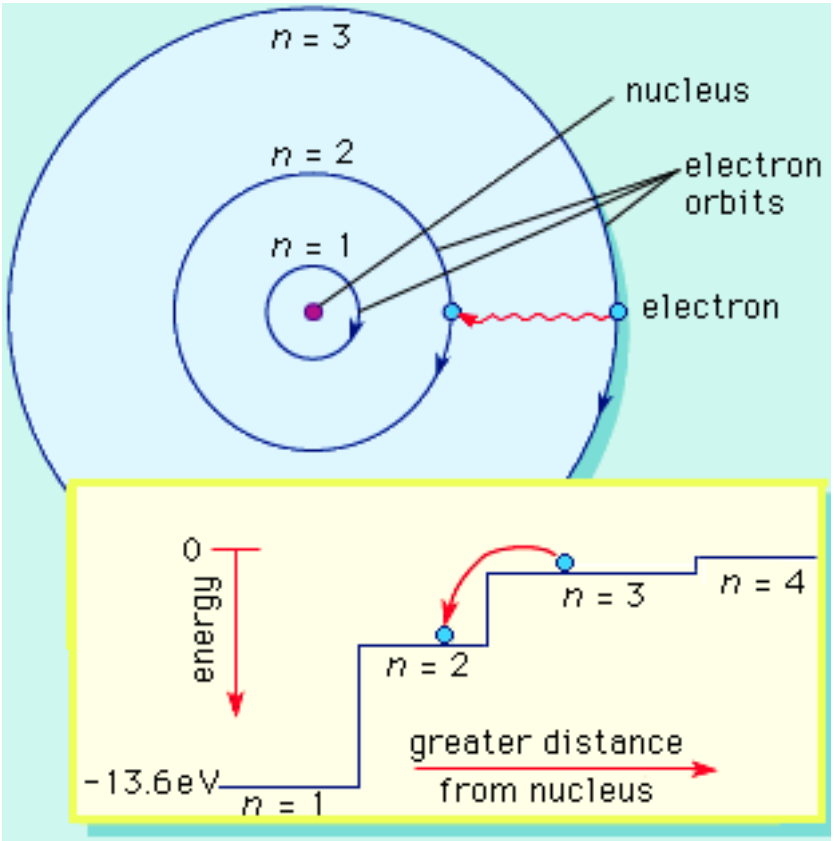
39. Switch to the **Schrödinger** model with **White** light and speed set to **Fast.** Describe what you see in the atom diagram and the energy level diagram. Don't worry about all the details. Just capture the big picture ideas.

40. Move the *Slow…Fast* slider all the way over to *Fast*, reset the **Spectrometer**, set **Light Controls** to **White**, and let the simulation run for 1 minutes.
41. Click on the **Spectrometer** camera to take a snapshot of the **Schrödinger** model. Compare it to the **Experiment**. Slide the snapshot off to the right for later comparison with other models.
    - How well does the **Schrödinger Electron Wave** model spectrum match the real hydrogen spectrum?

42. Spread the **Experimental** snapshot and the model snapshots across the screen. Push the "Print Screen" key at the top of the keyboard. This puts a snapshot of the screen on the computer's clipboard. Paste it into a Word document and print out two copies (one for each partner).

Homework

Consider the given diagram:
a) Which atomic model does it represent?
b) Summarise the main assumption of this model.
c) Why was this model accepted by the scientists?



Tutorial 4 – Absorption and Emission of Light by the Atomic Electrons

What is the Purpose of Tutorial 4?

- Recap what we learned about electromagnetic waves and the atomic models
- Explain the absorption and emission of light and how they happen inside the atom
- Calculate the energies of absorbed and emitted photons in a hydrogen atom

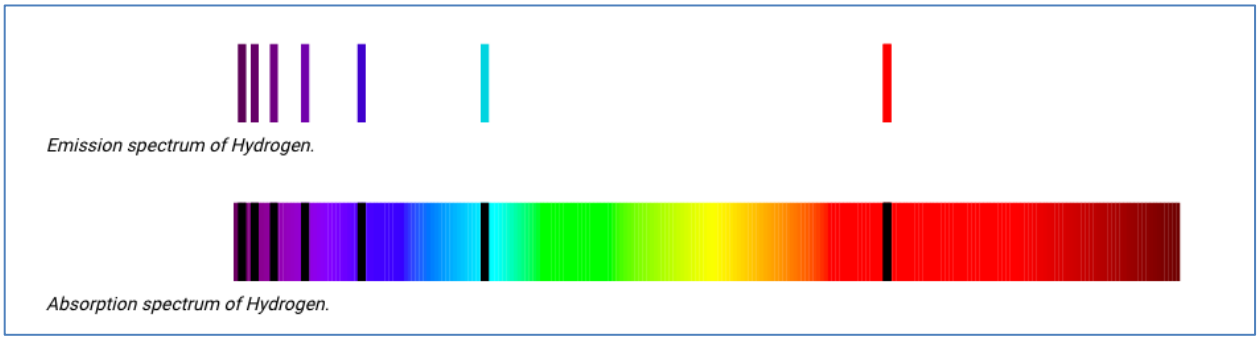


Figure 5: Emission and Absorption spectra of hydrogen.
Source: https://www.siyavulaeducation.com/

1. If white light shines into a tube of hydrogen gas, what colour of light will come out of the tube?

2. Why?

3. What will happen to the rest of the white light energies?

4. According to Bohr model, how many energy levels (shells) are in the hydrogen atom?

5. What does an electron need to move from one energy level to a higher one?

6. How will you do this experimentally?

7. What will happen to the electron after it reaches the higher level?

8. How will you observe this experimentally?

9. Explain what absorption spectra is for hydrogen.

10. Explain what emission spectra is for hydrogen.

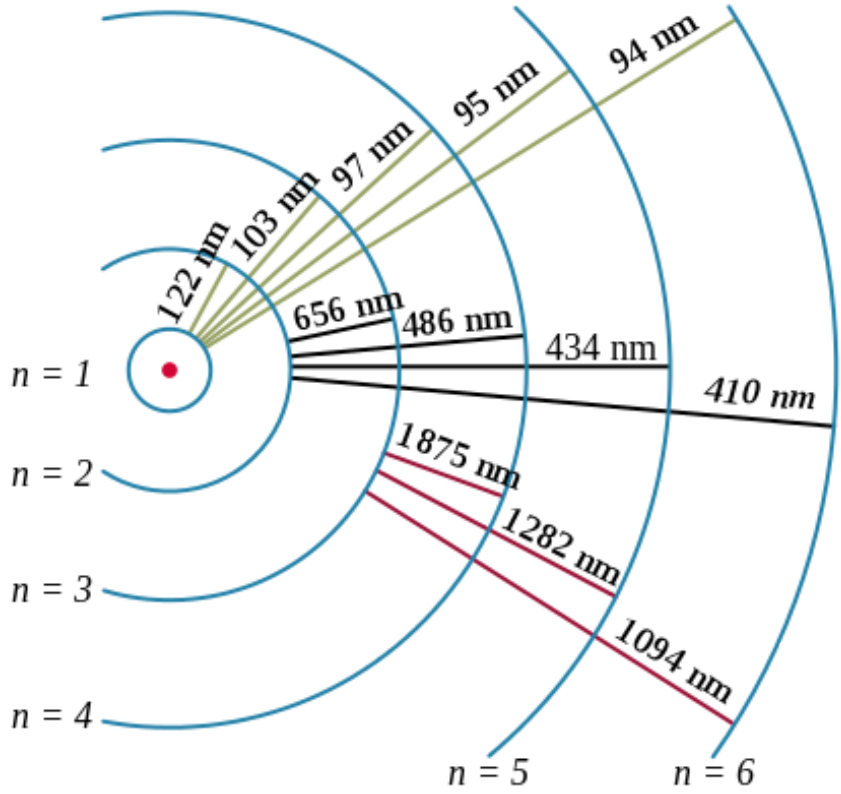


Figure 6: Energy levels in hydrogen atom.
Source: https://www.siyavulaeducation.com/

11. The above figure gives a schematic diagram of the spherical energy levels in hydrogen. What do the straight lines represent?

12. How will you excite an electron from n=1 to n=4?

13. Describe all the possible deexcitations that the electron may go through.

14. Calculate the energies of the emitted photons.

15. Which of these photons will be visible? What are their colours?

Homework

Consider the schematic diagram of the energy levels in hydrogen.
Which electronic transitions require absorption of visible light? Explain your answer.

Tutorial 5 – Applications of Atomic Physics

What is the Purpose of Tutorial 5?

- I can discuss how laser light is produced, based on the atomic physics principles
- I can explain how the He-Ne laser works

A- Laser Light

Figure 7: Laser lights: red (635-660 nm) , green(520- 532 nm), blue (6350660 nm)
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Overview of how a laser works

The word Laser is an acronym for Light Amplification by Stimulated Emission of Radiation. It also refers to the devices that produce the laser light.

A laser is created when the electrons in atoms or molecules in special materials (such as glasses, crystals, or gases) absorb energy from an electric current or another laser and become "excited". Most of the excited electrons return to their normal or "ground" state quickly. However, some excited electrons stay longer time in what is called ***metastable state***. A photon can disturb electrons in a metastable state. So, the electrons drop and emit a new photon that is identical to the original photon. This process is called ***stimulated emission***. These photons encounter more electrons in the metastable state, and the process repeats. The result is a cascade or a chain reaction of similar deexcitation (or stimulated emission).

Therefore, the laser device must be designed in ways that supplies energy to the electrons to be excited to metastable states and to support the stimulated emission process.

Activity 1: Spontaneous and Stimulated Emission

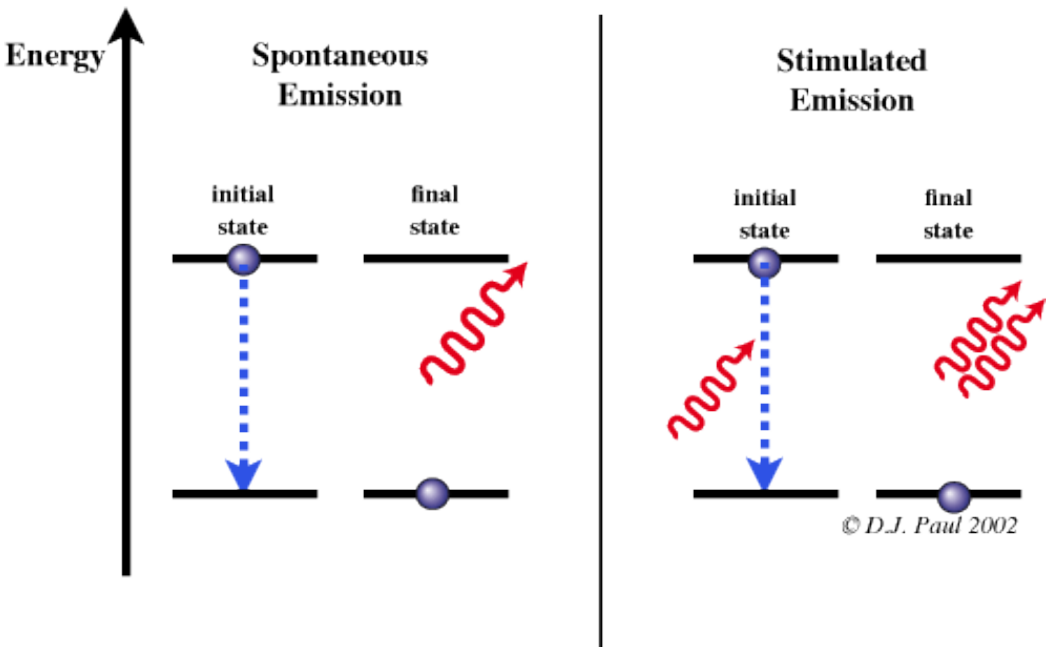

Figure 8: A schematic diagram of stimulated and spontoons emissions

In spontaneous emission, an electron in an excited initial state will decay spontaneously from a higher energy state to a lower energy state randomly. For lasing, however, stimulated emission is required where an electron in a metastable state is stimulated into a transition by a photon of the same energy as the transition to the lower state. The resulting photon stimulated by the first is emitted with the same phase and frequency as the first photon.

Questions:

1. How is laser light different from regular light?

2. Why do we use stimulated emission (not spontaneous emission) to produce laser?

Activity 2: Helium- Neon (He-Ne) Laser

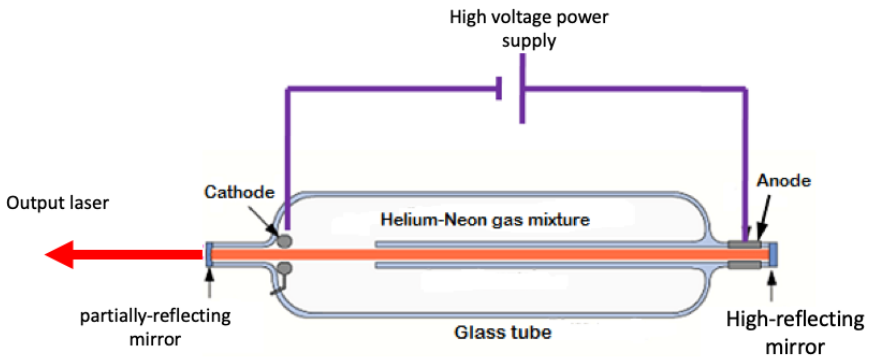

Figure 9: A schematic diagram of the helium-neon laser tube.
Source: https://www.physics-and-radio-electronics.com/physics/laser/heliumneonlaser.html

Components of the laser device

A laser tube, high-voltage power supply, and structural packaging.

- **Inside the laser tube:**
  The laser gas is a mixture of helium and neon in proportions of 9:1, at low presser.
  Mirrors, located at each end of the tube to increase the efficiency.
  A positive electrode (anode) and a negative electrode (cathode) are situated near each end of the tube (and connected to the power supply) to discharge electricity through the gas.

- **The power supply:**
  The power supply provides the high voltages needed (10 kV to start laser emission and 1-2 kV to maintain it). *Is this a high voltage? How do you compare this voltage to the voltage used for domestic appliances?*

- **<u>Structural packaging:</u>**
  The structural packaging consists of mounts for the laser tube and power supply. The laser may also include safety shutters to prevent random exposure and external optics to fine-tune the beam.

How does the He-Ne Laser work?

1. The gas mixture is placed at low pressure and the two gases are initially at their ground
2. states; He: $1s^2$, Ne: $1s^2\ 2s^2\ 2p^6$.
3. A high voltage is adjusted between the two electrodes (anode and cathode), which allows energetic electrons to pass through the gases.
4. The energetic electrons collide with He atoms.
5. He atoms become excited to a metastable state, He $1s^1\ 2s^1$, with energy ~ 20.6 eV.
6. The excited metastable He collides with Ne.

7. Energy, of 20.6 eV, transfers from He to Ne.
8. Inside each Ne atom, a single electron from 2p level transfers directly to 5s level, Ne: $1s^2\ 2s^2\ 2p^5\ 5s^1$. This big jump is made possible because Ne gains 20.6 eV energy. Now all of Ne atoms are in this meta-stable excited state.
9. Lasing, or the emission of the laser light, occurs in Ne atoms as 5s electron transfers to 3p level while emitting photon of 1.96 eV or 633 nm, red colour light. This happen as a spontaneous emission. It happens only to a few of the excited Ne atoms.
10. A 633 nm photon is released from one Ne atom and collides with another excited Ne atom. This stimulates the emission of a second photon with identical direction, frequency, and phase. The light flux has been amplified by a factor of two! These two identical photons collide with other Ne atoms and form a chain reaction and the light gets amplified. This stimulated emission process forms the essential step for the production of the red light by the He-Ne laser.
11. Photons emitted parallel to the long axis of the laser tube strike the mirrors and are reflected back along the axis, further increasing the amplification. (By contrast, photons which don't point down the axis of the cylinder will quickly leave the cavity and have fewer chances to collide with Ne atoms. These photons will not be amplified.) One of the mirrors is about 1% transmissive and this 1% of the laser light is the output of the laser. Imagine how bright it must be inside the tube!
12. Further, the Ne electrons at 3p make fast radiative transitions as they move to 3s. Then the Ne atoms lose all of their excitation energy through collisions with the walls of the tube. They return to the ground state and become ready for excitation again.

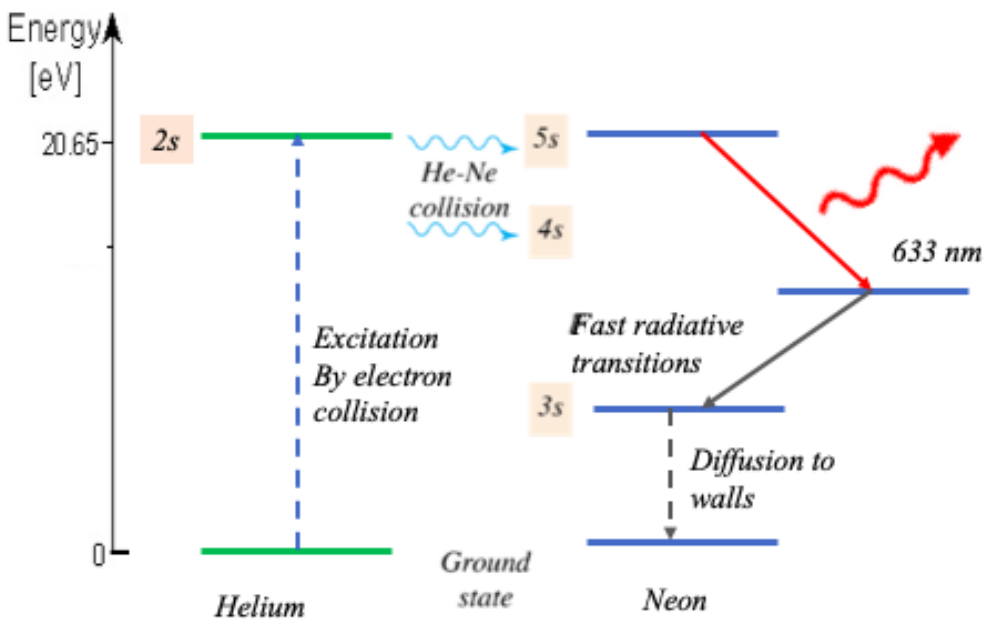

Figure 10:A schematic diagram of the energy levels in He-Ne laser

Final Assignment Title: Atomic physics and its applications

Details of the Assignment:

The modern models of the atom have marked a new era of our understanding of the building units of matter in nature and allowed us to recognize the fundamental links between matter and waves. This has led us to the invention of the laser light.

In light of this statement, write an essay that discusses the following points:

- The Bohr model of the atom;
- The developments to this model;
- When do atoms emit light;
- An application of atomic physics in another field.
- Include annotated diagrams or pictures in your essay.

<u>Important Notes:</u>

- Your essay should be well structured and easy to follow. It should Include an introduction, subheadings and a summary.
- You are encouraged to use resources beyond the workbook of this course and the school textbooks.
- Make sure you reference all your resources using the numbering system.

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 you use a reference?

You should use a reference when you:

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

How do I reference?

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

1. **A marker in your assignment**: After you have used a reference in your assignment (you have read something and included it in your work as a quote, or re-written it your own words) you should mark this is in your text with a number, e.g. [1]. The next time you use a reference you should use the next number, e.g. [2].

2. **Bibliography**: This is just a list of the references you have used in your assignment. In the bibliography, you list your references by the numbers you have used, and include as much information as you have about the reference. The list below gives what should be included for different sources.

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

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

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

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

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

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

Notes

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