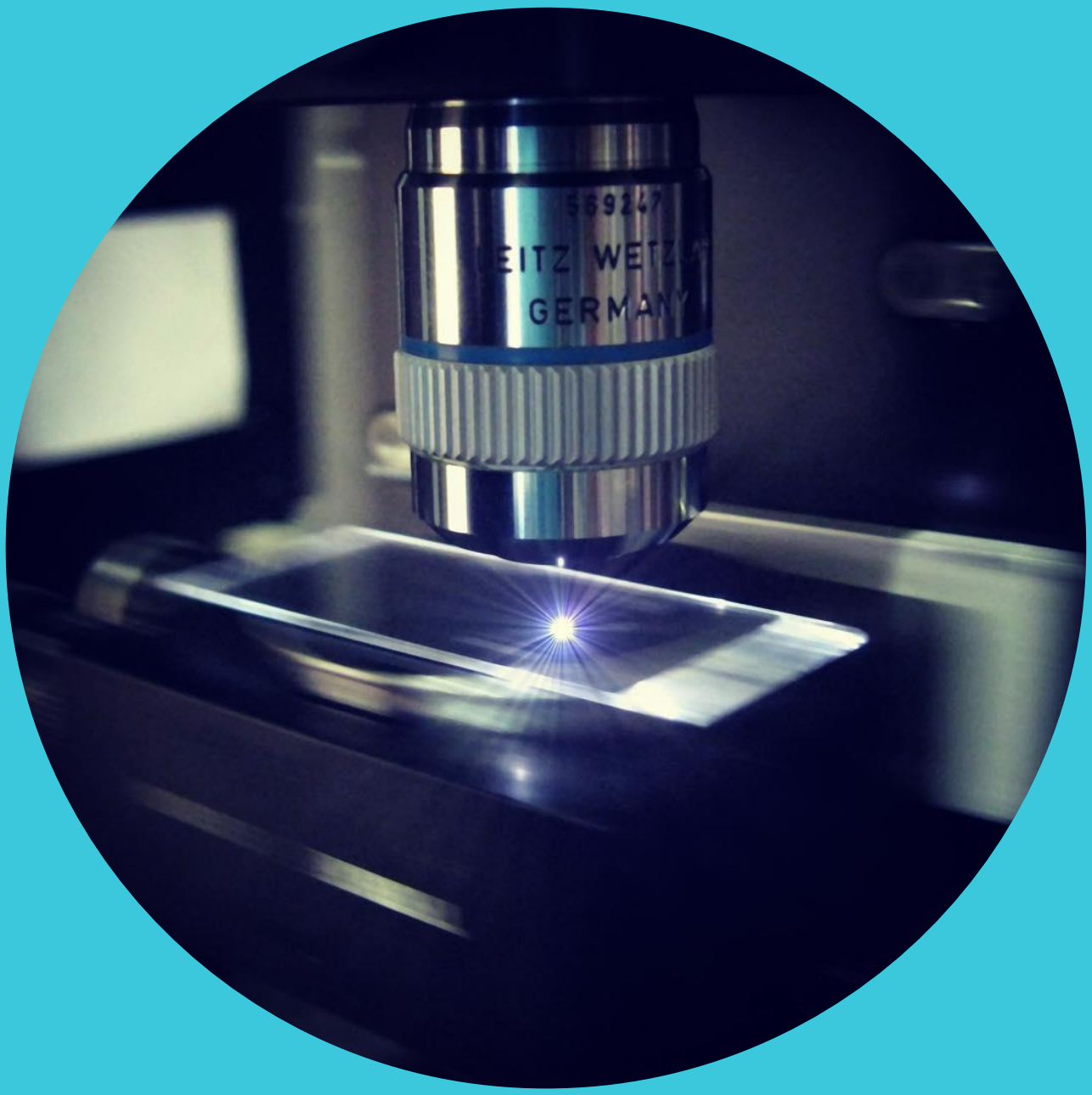
Researchers in Schools



The 3D laser pen:

How to save the world from an electrical meltdown

Pupil Name

Coursebook Designed by **Dr. Pereira Lopes**

Timetable and Assignment Submission

Timetable – Tutorials

Tutorial	Date	Time	Location
1	2nd December		Senate House Library
2			T2C
3			T2C
4			T2C
5			T2C
6 (Feedback)			T2C
7 (Feedback)			T2C

Timetable – Homework Assignments

Homework Assignment	Description	Due Date
Tutorial 1	Write a 450-550 words essay in which you present a simple scheme of a laser direct writing setup.	
Tutorial 2	In a 250-500 word text present the laser assigned to you, writing about all laser light characteristics.	
Tutorial 3	In a 250 - 500 word text, further characterize your laser source.	
Tutorial 4	In a 250-500 word text apply the concept of discrete levels of energy to your specific laser/application.	
Tutorial 5	Write a final 2000 words essay where you bring together all the work done until now in the baseline assignment and homework done from the previous tutorials.	

Assignment Submission – Lateness and Plagiarism

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

Contents

Course Rationale	**4**
Mark Scheme	**5-8**
Glossary of Keywords	**9-10**
Tutorial 1	**11-14**
Activity 1	**12**
Activity 2	**12**
Activity 3	**13-14**
Tutorial 2	**15-18**
Activity 1	**16**
Activity 2	**17**
Activity 3	**17-18**
Tutorial 3	**19-20**
Activity 1	**19**
Activity 2	**20**
Tutorial 4	**21-24**
Activity 1	**22**
Activity 2	**23**
Activity 3	**24**
Tutorial 5	**25-27**
Activity 1	**25-26**
Activity 2	**26**
Activity 3	**27**
Tutorial 6	**28-29**
Reflection on feedback	**29**
Tutorial 7	**30-31**
Reflecting on the course	**31**
Appendices	**32-34**
Referencing correctly	**32-33**
General info	**34**

Course Rationale

Light is the ultimate source of life. Without the sun's light earth would quickly freeze and most if not all animals would be brought to extinction.

Human ability to master light was crucial in increasing our power over nature. Artificial illumination was just the start of our journey. In the past century lasers have been more and more involved in our lives. Not only as the pointers that our four-legged felines so much adore to chase, but also in surgeries, medical exams, in factories for cutting and aligning materials, and finally communicate more efficiently than through electricity. This last point will be our target for our course. In many homes now internet runs through fibre optical cables, which means we are already using light to transfer information faster and more efficiently than we could with electrical wiring. Laser direct writing is a tool that enables us to create "paths of light" inside a bulk piece of glass, and with that create all types of devices that manipulate these light signals.

With this course you will gain a better understanding of how a laser works, and what makes it so special as a light source. You will learn a lot about the nature of light, and with this powerful knowledge you can unveil many mysteries of the world around you. The course will end with a focus on how lasers can be used for directly writing inside glasses, and how they can help substituting electrical by optical communications.

This course will help you develop a better understanding not only for your physics GCSE curricula but also beyond. We will use whenever possible numerical calculations with real examples to help you ground all these concepts in reality. This will develop both your numeracy skills and critical thinking. Finally, by writing a university style essay, you will also develop important skills such as how to write scientifically, reference your sources, and the presentation of data through graphs and tables.

Uni Pathways Mark Scheme 2019 – Essay-based assignments

	Skills	1st (70-100)	2:1 (60-69)	2:2 (50-59)	3rd (40-49)	Mark /100
Subject knowledge	Knowledge and understanding	o All content included and materials used are relevant to the general topic and to the specific question/title o Good understanding of all the relevant topics. o Technical terms are defined and used accurately throughout o Clear justification of how the material and content included is related to the specific issues that are the focus of the assignment	o Most of the materials used and content included are relevant to the general topic and to the specific question/title o Good understanding of most the relevant topics o Technical terms are mostly defined and used accurately o Adequate justification of how the material used and content included are related to the specific issues that are the focus of the essay	o Some of the materials used and content included are relevant to the general topic and to the specific question/title o Good understanding on some of the relevant topics but occasional confusion on others o Technical terms are sometimes used and defined accurately o Some justification of how the material used and content included are related to the specific issues that are the focus of the essay	o The content included and materials used are not applied to the question/title in a relevant manner o There is confusion in how understanding of the topics is expressed	
Critical thinking	Research and evidence	o Includes rich sources of research findings, data, quotations or other sourced material as evidence for the claims/ideas o Uses evidence/calculations to support claims/assertions/ideas, consistently clearly and convincingly o Evidence of further reading beyond materials provided which were used in an appropriate context	o Includes adequate sources of research findings, data, quotations or other sourced material as evidence for the claims/ideas o Uses evidence/calculations to support claims/assertions/ideas, mostly clearly and convincingly o Evidence of further reading beyond materials provided	o Includes some sources of research findings, data, quotations or other sourced material as evidence for the claims/ ideas o Uses evidence/calculations to support claims/assertions/ideas, at times clearly and convincingly o Limited evidence of further reading beyond materials provided	o Inclusion sources and materials is very limited and mostly not attributed o Applicable sources are rarely used to support ideas. o Data is not used or few appropriate conclusions are drawn from it.	
	Developing an argument	o A point of view or position in relation to the title or question is consistently clear. The position is developed effectively and consistently throughout the essay o Argument is exceptionally well-developed and well-justified o Makes links effectively between subjects that have not previously been associated o Uses concepts from the tutorials in an unfamiliar context and does so accurately and confidently. o Content is analysed effectively to support the argument	o A point of view or position in relation to the title or question is adequately clear. The position is well-developed in most of the essay o Argument is clear and well-developed, and position is justified o Some evidence of linking subjects that have not previously been associated o Uses some concepts from the tutorials in an unfamiliar context, but not always accurately o Analyses content to support the argument	o A point of view or position in relation to the title or question is somewhat clear. The position is well-developed in parts of the essay o Argument is clear but not well-developed o Limited evidence of linking subjects that have not previously been associated o Limited use of concepts from the tutorials in other contexts o Uses some analysis of content to support the argument	o There is not a clear point of view or position taken and sometimes the argument is not clearly established	

	Critical evaluation	○ Moves beyond description to an assessment of the value or significance of what is described ○ Evaluative points are consistently explicit/systematic/reasoned/justified ○ Effectively critiques the reliability of sources provided	○ Mostly description but some assessment of the value or significance of what is described ○ Evaluative points are mostly explicit/systematic/reasoned/justified ○ Some evidence of critiques on the reliability of sources provided	○ Describes with minimal assessment of the value or significance of what is described ○ Evaluative points are at times explicit/systematic/reasoned/justified ○ Limited evidence of critiques on the reliability of sources provided	○ The work is descriptive in nature and there is a lack of critical engagement in the value of sources	
Written communication	Structure and presentation	○ Ideas are presented in paragraphs and arranged in a logical structure that is appropriate for the assignment ○ The introduction clearly outlines how the essay/report will deal with the issues ○ The conclusion summarises all the main points clearly and concisely ○ All calculations, formulas and methods are clearly structured, clear to follow and correct ○ Tables and graphs are effectively constructed including appropriate headings, units and scales. ○ All sources are referenced correctly in an agreed format	○ Ideas are presented in paragraphs and arranged in a structure that is mostly appropriate for the assignment ○ The introduction adequately describes how the essay/report will deal with the issues ○ The conclusion summarises most of the main points clearly ○ Calculations, formulas and methods are mostly structured, clear to follow and correct ○ Most tables and graphs are well constructed ○ Most sources are referenced correctly in an agreed format	○ Ideas are presented in paragraphs and arranged in a structure ○ The introduction mentions how the essay/report will deal with the issues ○ The conclusion summarises some of the main points clearly ○ Calculations, formulas and methods are not always structured, clear to follow and correct. ○ Some tables and graphs are well constructed but contains some errors ○ Some sources are referenced correctly in the agreed format with occasional errors	○ Ideas are presented in paragraphs but there is a lack of structure in how the work is presented ○ The work lacks an introduction that establishes the scope of the question ○ The work lacks a conclusion that summarise the main points raised ○ Work is not referenced accurately	
	Language and style	○ No spelling, grammar or punctuation errors ○ Writing style consistently clear, tone appropriate and easy to follow ○ Accurate and consistent use of technical language and vocabulary	○ Minimal spelling, grammar or punctuation errors ○ Writing style mostly clear, tone appropriate and easy to follow ○ Some attempts of using technical language and vocab alary, but not always accurate	○ Some spelling, grammar or punctuation errors ○ Writing style moderately clear, tone appropriate and easy to follow ○ Use of simple language and vocabulary effectively but struggles to use technical language	○ There are a significant number of spelling, grammar and punctuation errors ○ Use of simple language and vocabulary effectively but a lack of technical language	
Overall Mark (average of the 6 marks from the criteria above)						

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

Knowledge and Understanding		Research and Evidence	
	mark		*mark*
Developing an Argument		**Critical Evaluation**	
	mark		*mark*
Structure and Presentation		**Language and Style**	
	mark		*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

Knowledge and Understanding		Research and Evidence	
	mark		*mark*
Developing an Argument		**Critical Evaluation**	
	mark		*mark*
Structure and Presentation		**Language and Style**	
	mark		*mark*

Subject Vocabulary

Vocabulary

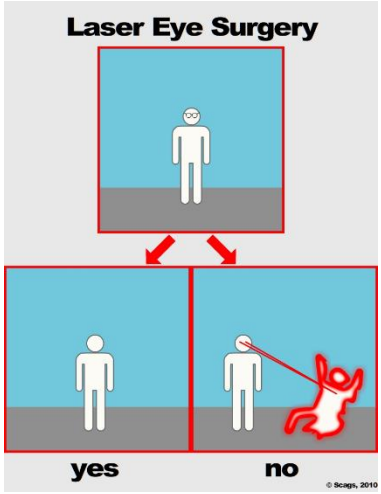
#	Word	Definition	Used in a sentence
1	Laser	Device that allows the production at the output of coherent and non-diverging light beam	
2	(light) beam	Directional projection of light in a specific direction, with reduced divergence.	
3	Focus	Point at which light is concentrated in the smallest volume	
4	Refraction	The process that occurs when light passes from a medium to another, generally changing its direction.	
5	Fibre	Device in the form of a cable where light can propagate in it without diverging,	
6	Pulse	Emission of a "burst" of light for a short period of time.	
7	Convex lens	Lens with an oval shape, that focuses light.	
8	Concave lens	Lens with inverted shape compared to the convex, that diverges light.	
9	Lens	Device, normally made of glass used for manipulating divergence of a light beam.	
10	Linear/non-linear absorption	Absorption of a single/multiple photons by an electron.	
11			
12			
13			
14			
15			

16			
17			
18			
19			
20			
21			

Physical quantities

#	Word	Definition	Used in a sentence	S.i. units
1	Divergence	The measure of how much light spreads over a distance, normally measured in degrees.		
2	Wavelength	Length that a wave needs to travel until it repeats itself.		
3	Frequency	Number of times an event repeats itself per second.		
4	Refractive index	The refractive index of a medium determines how fast light can travel in it.		
5	Repetition rate	Number of pulses of light per second that a laser emits.		
6	Bandgap	Difference in energy between ground and excited state of an electron.		
7				
8				
9				

Tutorial 1 – What can a laser do for you?

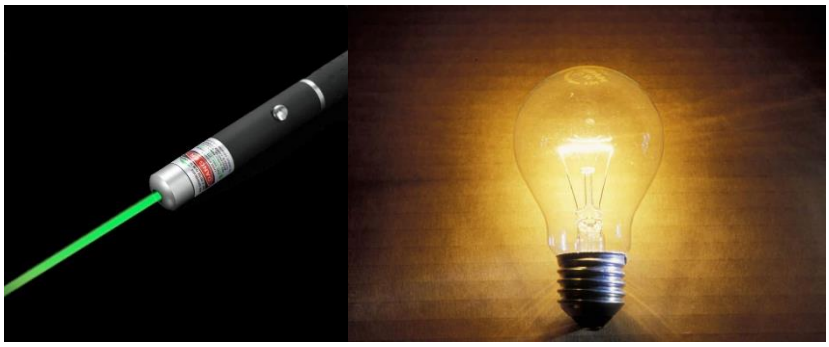


What is the Purpose of Tutorial 1?

- Distinguish what are the main differences between light coming from a laser and a lamp.
- Understand the working principle of a laser, and a direct writing setup.
- Identify a set of applications of lasers, particularly in direct writing.

Starter- Laser vs lamp

Fill the table with the main characteristics light, and on the respective columns how they are different between a laser and an incandescent lamp.

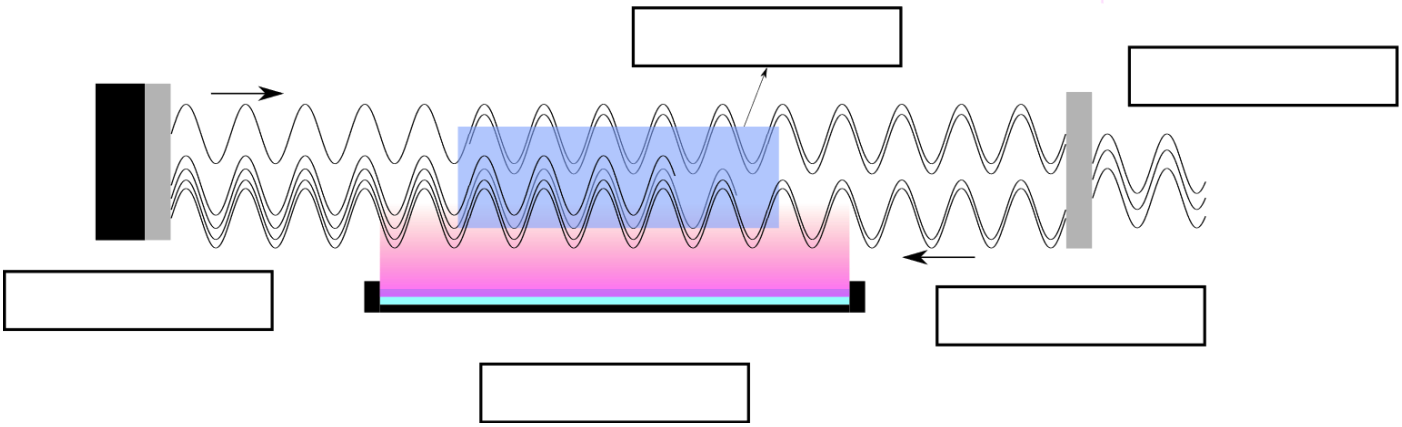


Characteristic	Laser	Incandescent Lamp

Activity I- The laser scheme

a) Fill the scheme and text with the following key words:

100% mirror/partial mirror/ active medium/output beam/ pump source

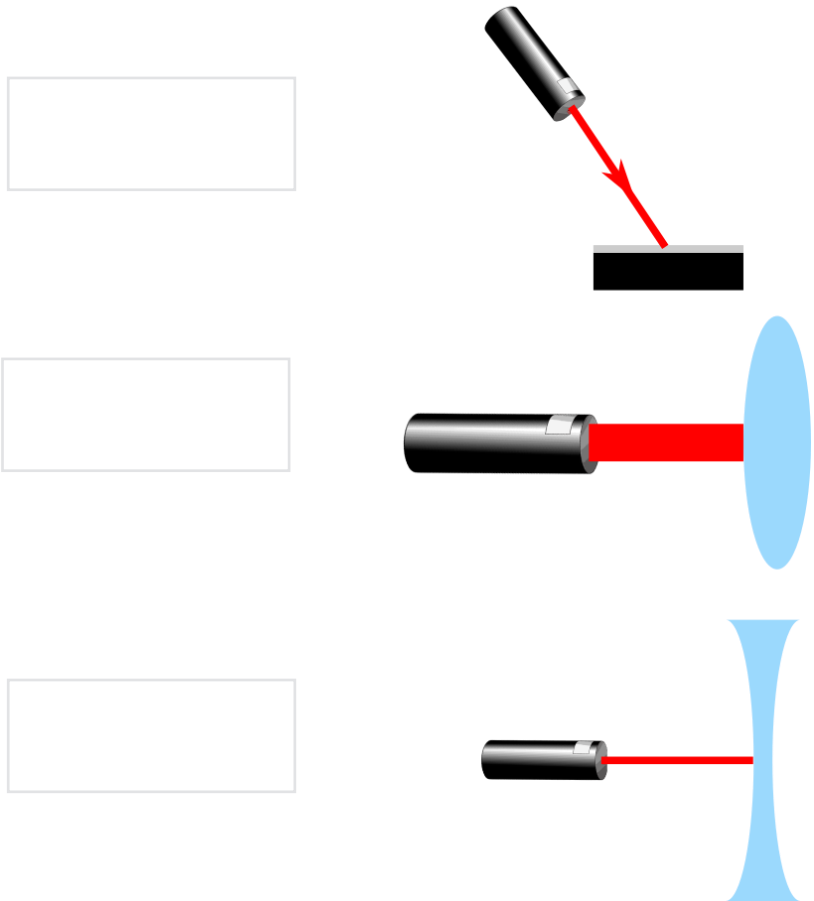


Laser: l _ _ _ _ a_ _ _ _ _ _ _ _ _ _ _ _ _ by s _ _ _ _ _ _ _ _ _ _ e _ _ _ _ _ _ _ _ of r _ _ _ _ _ _ _ _ _

How a laser works:
The _____ (flash lamp) light is absorbed by the _____. When light is propagating in the vicinity of the _____, it can emit another ray that oscillates in resonance/dissonance with the first one. This process repeats itself since light reflects back and forth on the _____ and _____, which increases the power inside the laser exponentially. Since the _____ does not reflect light completely, after the laser accumulates a lot of light inside it starts leaking, giving an _____ that is confined and coherent.

Activity II- My optics library

Fill the blanks with the following optics components names: mirror/ converging lens/ diverging lens.
For each of the optics components draw the shape and direction of the beam after it interacts with them.



Activity III- My laser direct writing setup:

Pasting the components given to you design your own direct writing setup. After placing the components draw the output beam from the laser source until the end.

Write in your own words a description of how your laser system works.

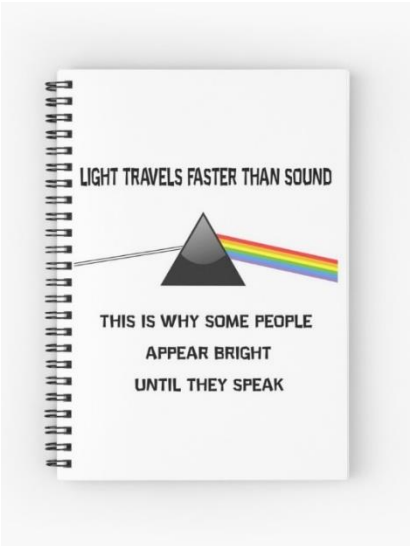
Baseline assignment

Write a short (450-550 words) essay in which you present a simple scheme of a laser direct writing setup (drawn by you, either on a computer or a piece of paper). Finally, you should explain how your laser is used in the real-world application that was chosen by you.

Success criteria:

- Include content that is relevant to the topic and the specific assignment/homework title or question.
- Include key words from the glossary and demonstrate that you understand them by explaining what they mean and how they relate to the topic.
- Include research findings from a wide range of sources. As well as using the sources provided, you should be discovering some sources yourself from the independent work that you do outside tutorials.
- Give reasons and evidence to back up the points that you make. You might find the PEE structure helpful:
    - Point – make the key point clear
    - Evidence – explain the evidence for the point
    - Explanation – explain why your point is relevant and important
- Include critique, evaluation and/or response to the problem-set.
- Organise your ideas in paragraphs with a logical structure.
- Include an introduction that clearly outlines what the assignment will contain.
- Include a conclusion that summarises all the key points clearly.
- Make sure your calculations, formulas and methods are clear and structured correctly.
- Make sure that you have referenced everything correctly.
- Make sure your spelling, grammar and punctuation are accurate.
- Use a formal style of writing that is appropriate for an academic essay

Tutorial 2 – What is light?



What is the Purpose of Tutorial 2?

- Have a better understanding of what is light.
- Identify its different properties.
- Argue why it is interesting to have laser light in short pulses, and how this is done.

Starter- Light in all its dimensions

Think and write in your exercise book as many characteristics and properties that you remember of light. As we brainstorm together on the board fill the white space around the figure. Feel free to come back here and add more concepts as we go through the tutorials.

Activity I- Frequency and wavelength : The two fighting sisters.

a) Complete the box bellow with the physical quantities in the light velocity equation.

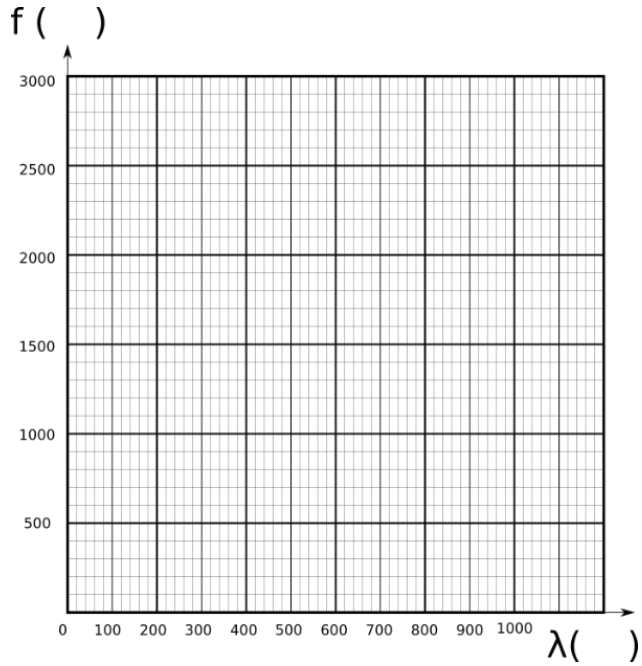
$$v = f \times \lambda$$

	=	x

b) Light speed is constant and always equal to v=c=3 x 10^8 m/s.
Using this information calculate for the following colours wavelengths what is the corresponding frequency.

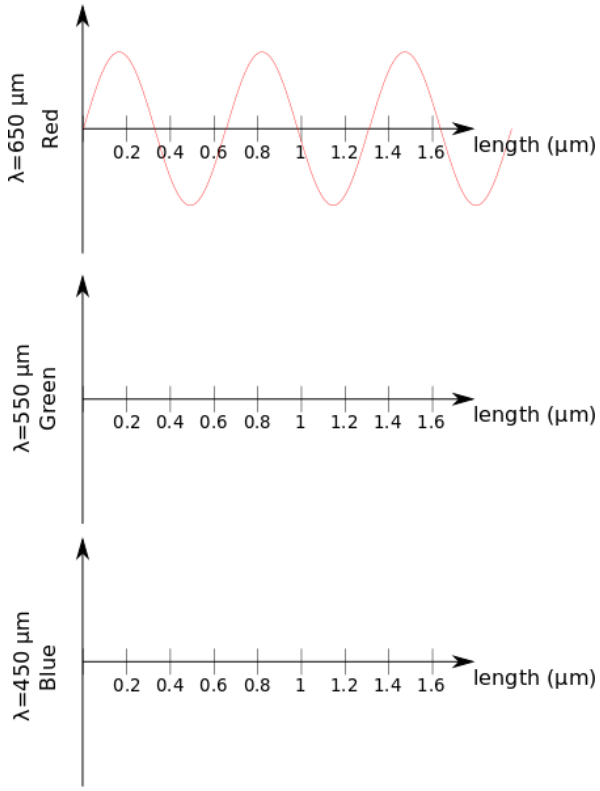
c) Draw the points calculated on the graph and connect the them with a trending curve.

Colour	Wavelength (nm)	Frequency ( )
Infra-red	1000	
Red	650	
Orange	600	
Yellow	575	
Green	550	
Blue	450	
Violet	400	
Ultra-violet	100	



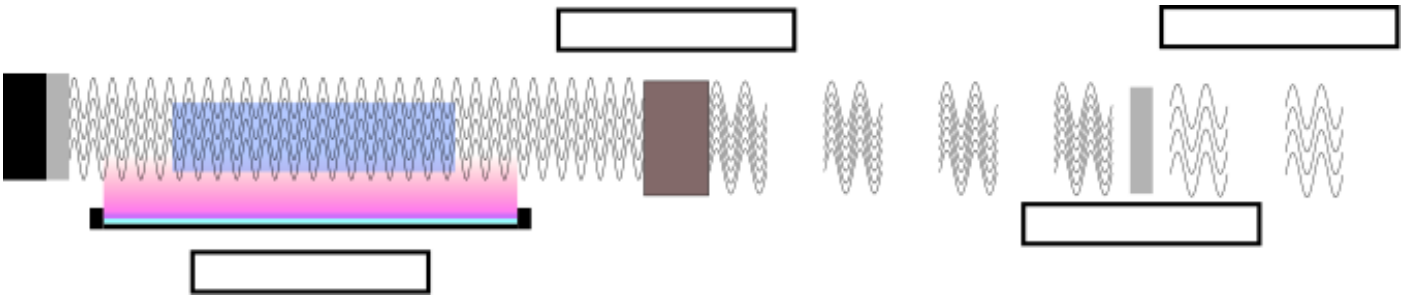
d) What will be light's frequency if the wavelength grows very large (λ→inf)? And if it is very small (λ→0)?

e) In the first graph bellow you see a graphical representation of a light wave of red colour propagating in space. Draw the missing waves of green and blue colour.



Activity II- Pulsing light : concentration is the key

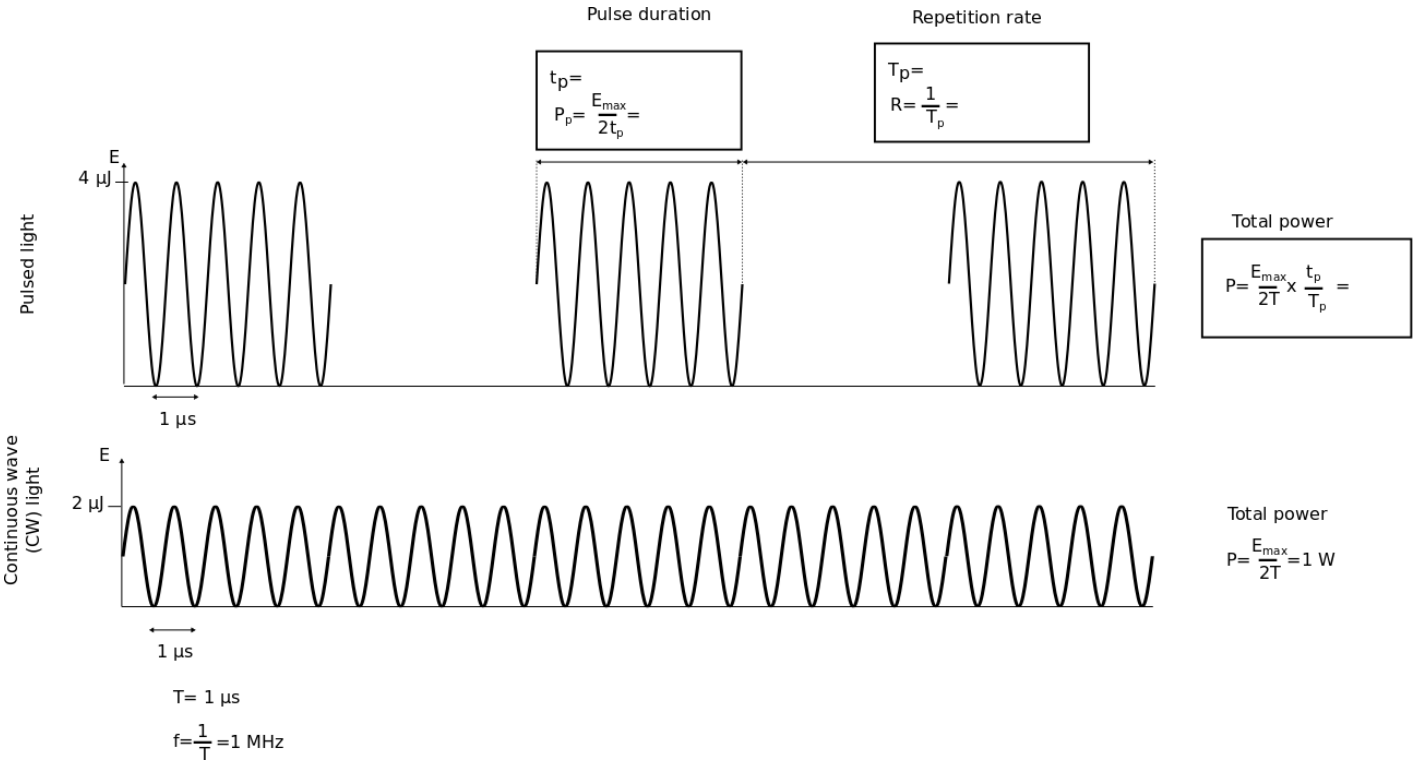
a) Fill in the blank boxes/spaces with the following key words:
laser source/ saturable absorber/partial reflector/output pulsed beam



One of the ways of making a pulsed laser is by using a _____ inside the laser cavity. The _____ inside the laser cavity is initially absorbed by the _____ until it saturates. Once saturated it becomes transparent/opaque and so lets light pass. After a short time the saturable absorber becomes again transparent/opaque. This cycle is why we have an _____.

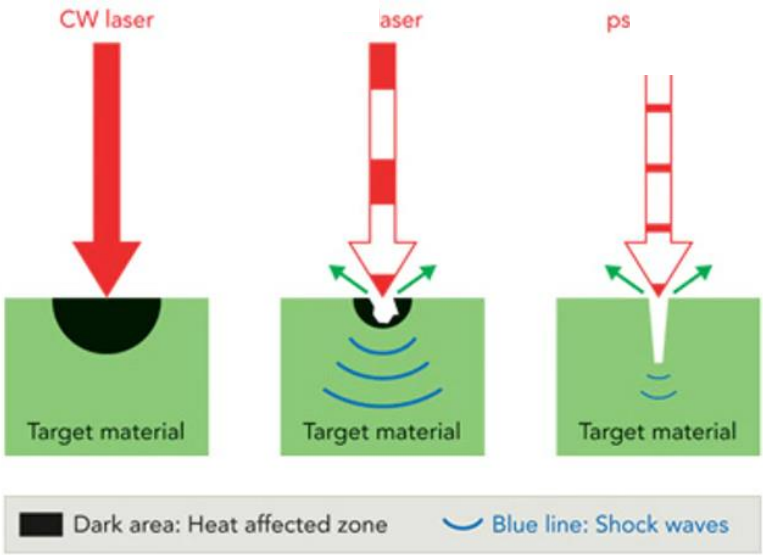
Activity III- Pulsed laser vs continuous wave (CW) laser damage: It's all about precision.

a) In the signalled boxes make the calculations of pulse duration, repetition rate and total power of the pulsed light.
b) Complete the sentences bellow the figure.



Having a pulsed laser light has advantages because while the total power that is delivered is higher/lower/the same as the power of CW light, the pulse power (P_p) is higher/lower/the same.
The repetition rate of a pulsed laser gives the _____ per _____.
The lower the pulse duration, the higher/lower will be the pulse power (P_p).

c) The figure bellow shows the difference on the damage done by a CW and a pulsed laser for two different pulse durations. Fill in the table with the differences observed in the figure.



	CW	ns (10^{-9} s)	ps/fs (10^{-12} – 10^{-15} s)
Heat accumulation			
Size of the damage			
Type of damage			

Homework

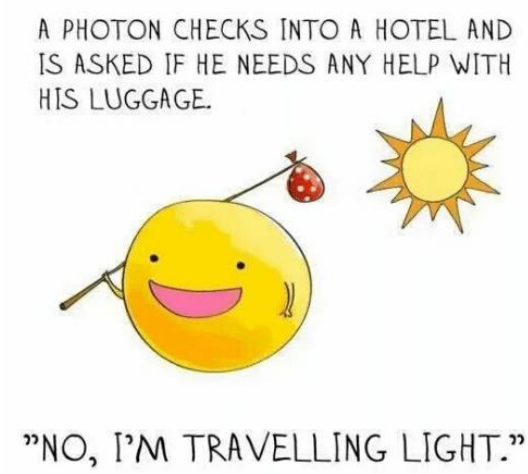
Fill the columns "used in a sentence" of the vocabulary section and the S.I. units for the physical quantities of the new concepts learnt. Add any other new words in the vocabulary section so they can be defined by next tutorial.

Write a 250-500 word text presenting the laser assigned to you, writing about all its laser light characteristics. Calculate the frequency of the light. Use as much as possible all the new vocabulary learned in this lesson. Calculate the peak power and compare it to the total power of the laser and other sources of light. End the text by arguing why a pulsed laser is better than a continuous wave laser for your application.

Tutorial 3 – Photons: light's little minions

What is the Purpose of Tutorial 3?

- Understand what photons are.
- Distinguish the difference between intense light and energy of each photon.
- Understand how wavelength, frequency, and photon energy are connected.



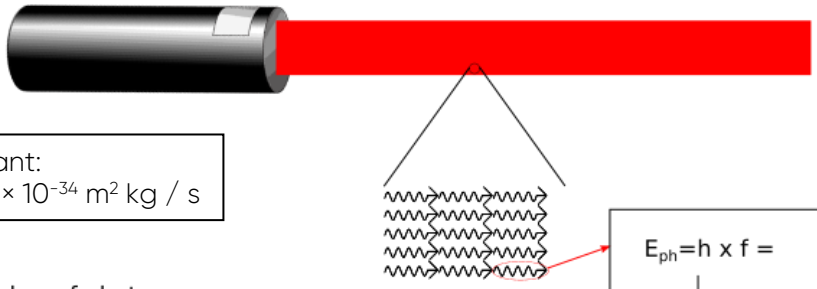
Starter- Photons: light's sneaky secret

Light hides a little secret. It is actually made of smaller particles called photons. But how many photons are there in a normal laser beam? Let's see!

a) Finish the calculations in the boxes bellow. Hint: to calculate the frequency of the laser light check tutorial 2-activity I.

P= 1 mW

λ= 650 nm



Planck's constant:
h= 6.62607004 × 10^{-34} m^2 kg / s

E_{ph}=h x f =

= x

Number of photons

In a second: E= P x t =

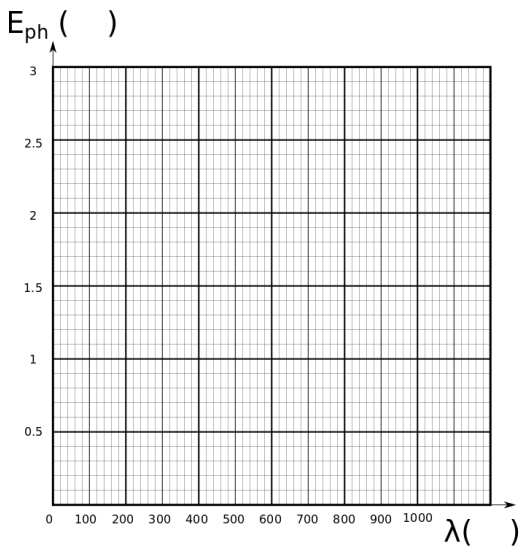
Number of photons: $N_{ph} = \frac{E}{E_{ph}}$ =

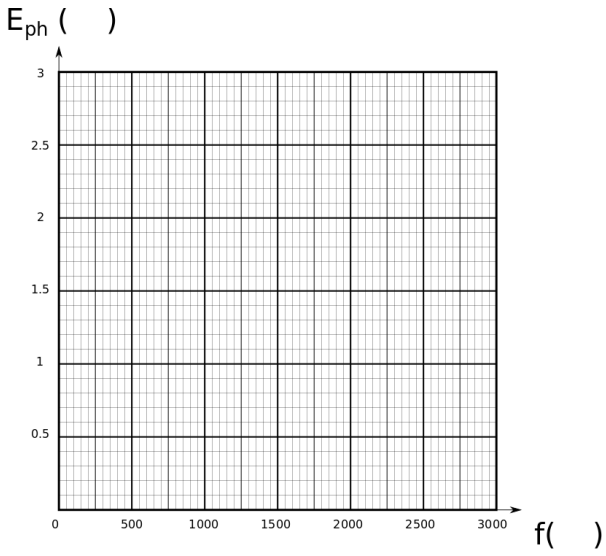
Activity I- Photon wavelength and its energy: energetic colours

a) Using the above equation calculate the values of photon energy that correspond to each wavelength/frequency.

Colour	Wavelength λ (nm)	Frequency f ( )	Photon energy E_{ph} ( )
Infra-red	1000		
Red	650		
Orange	600		
Yellow	575		
Green	550		
Blue	450		
Violet	400		
Ultra-violet	100		

b) With the values calculated in the table above, fill the two graphs and draw a trend curve.





Light's colour (or more scientifically _____) corresponds to a single of _____. This means that the photons from violet light have more/less/the same energy that the ones from red light. As frequency of light increases, wavelength increases/decreases and photon energy increases/decreases.
The power of laser light is dependent/independent of the energy of its photons. This means that a red laser light can have higher or lower power than an ultraviolet laser, depending only on the construction specs of the laser itself.

Activity II- Photon energy vs Average Power: so similar yet so different

a) Complete the following table and correct the sentence bellow.

	Low photon energy	High photon energy
Low power	Effects:	Effects:
	Example:	Example:
High power	Effects:	Effects:
	Example:	Example:

Light's power and photon energy sound like they are synonyms but, they can change independently. This means that the effects of a high power infra-red laser are similar/different than a low power ultra-violet laser.

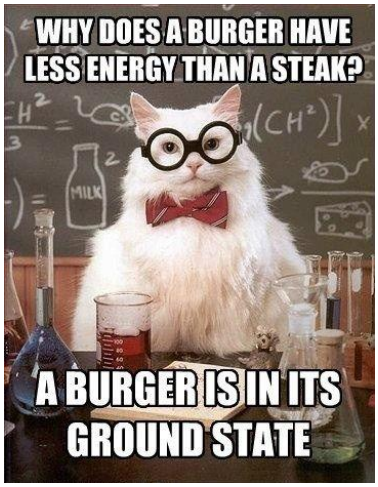
Homework

Fill the columns "used in a sentence" of the vocabulary section and the S.I. units for the physical quantities of the new concepts learnt. Add any other new words in the vocabulary section so they can be defined by next tutorial.
In a 250 - 500 word text, further characterize your laser source. Calculate the photon energy, number of photons per second, the frequency and the class of wavelength (visible/IR/…) (check appendix if necessary). Finally compare your photon energy and power with the one of a laser pointer and a lamp, and argue why your source is the right for your application.

Tutorial 4 – Energy levels, absorption and emission

What is the Purpose of Tutorial 4?

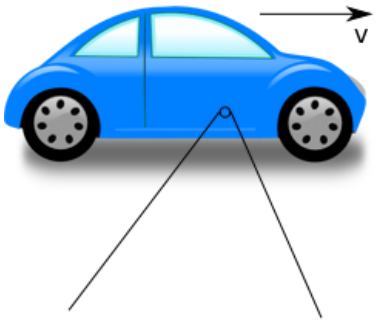
- Familiarize with the concept of discrete energy levels.
- Explain the difference between linear and non-linear absorption.
- Describe how non-linear absorption is used for writing in 3D inside glass.

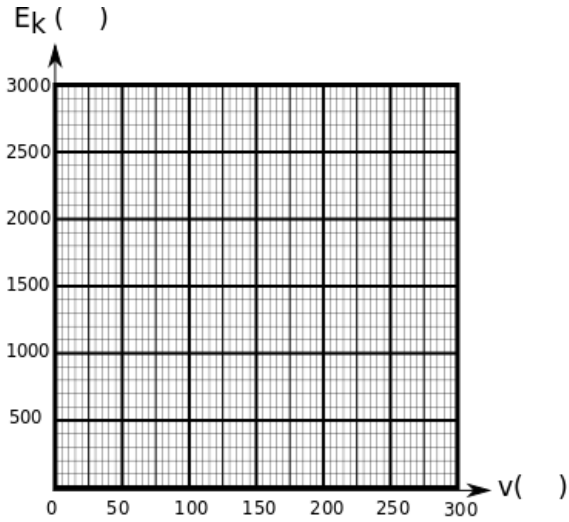


Starter- Discrete energy states : it's a whole other level!

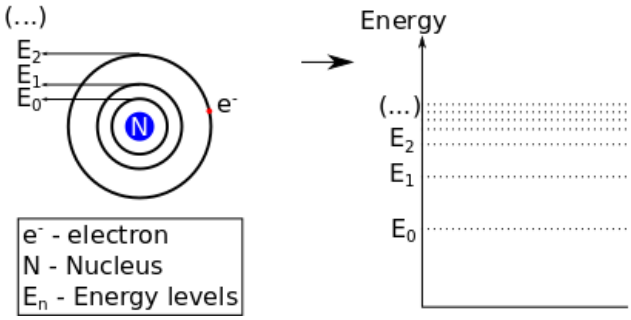
a) First consider the car travelling at a given speed. Calculate the kinetic energy using the respective equation, completing the table on the right. Consider the car has 1 kg of mass.
b) Add the velocity/kinetic energy values to the table and draw a trend curve.

$E_k = 0.5 \times m \times v^2$





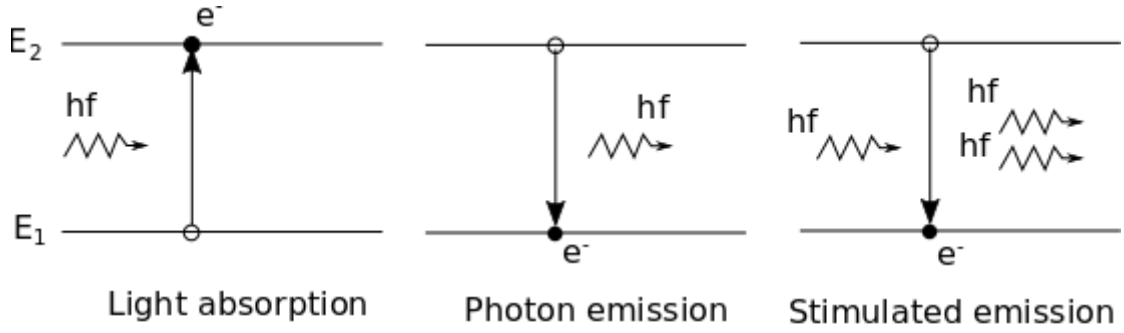
Velocity (km/h)	E_k - Kinetic energy (J)
10	
50	
100	
150	
200	
250	
300	



c) Fill the empty spaces and cross the wrong options:
In the case of macroscopic objects like the car in the figure, its kinetic energy is continuous/discrete since when it accelerates from 0-300 km/h it passes through all the possible energy values between _____ and _____.
However if we zoom in the atomic scale, the energy levels are continuous/discrete. This means that the _____ can only have specific levels of _____ that correspond to different orbitals around the nucleus.

Activity I - Light absorption and emission: what you give is what you get.

a) The figure shows the three different possibilities that can happen when an electron interacts with a photon. There is a single equation that relates the Planck constant h, the photon frequency f, and the two energy levels considered here E_1 and E_2. Hint: Law of conservation of energy.



Equation

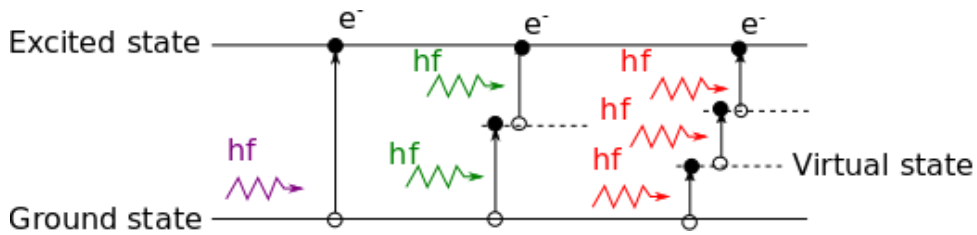
b) Complete the text bellow

Light absorption: If a photon has high enough _____ it can be absorbed by the _____, so it gets excited.
Photon emission: An excited _____ can lose energy by emitting a _____. The photon energy will have equal/more/less energy than the one lost by the electron.
Stimulated emission: If a photon is in the vicinity of an _____ _____, it can stimulate it to emit a second photon. Both photons will be/won't be synchronous.

Challenge: Go back to the laser scheme in Tutorial I-activity II. Why is stimulated emission crucial for how a laser works?

Activity II- Non-linear absorption: when one is not enough.

a) The diagram shows the different possibilities for the absorption of photons by an electron. The colour of the photons corresponds to their wavelengths (400 nm, 450, 650 nm)



When a photon has higher/lower energy than the bandgap (Excited state minus ground state energy) we can have linear absorption.
If the _____ not enough energy to excite the _____, then if two or more photons are in the same vicinity, they can together excite the electron. This is called non-linear absorption. This process is rarer/more frequent than the linear absorption, since you need two photons simultaneously in the same place, instead of just one.

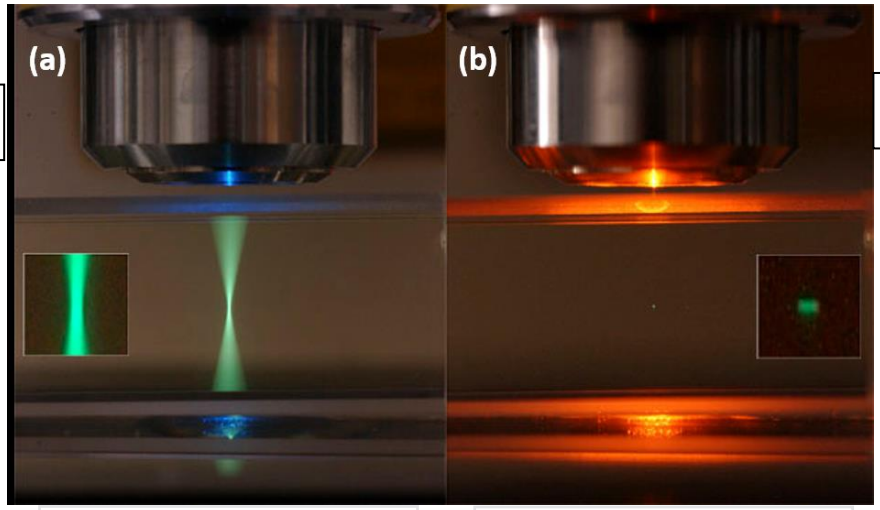
Challenge: Why do photons of different colour interact differently? Can you use the wavelength to estimate the bandgap (Excited state-Ground state energies) present in this example?

Activity III- Linear vs Non-linear absorption: Because sometimes harder is better.

The figure shows two different lasers lights being focused inside glass.

a) Write the corresponding wavelengths to the laser colour.
b) On the box bellow each image write the correct type of absorption observed: Linear/non-linear absorption.

λ=



λ=

c) Knowing that the bandgap of this glass is 2.15 eV=3.44x10^{-19} J, how many photons are used in this non-linear absorption case?

d) What about if we use a laser source with a wavelength of 1.5e^{-6} m? Will it still be non-linear? If so how many photons are necessary?

Homework

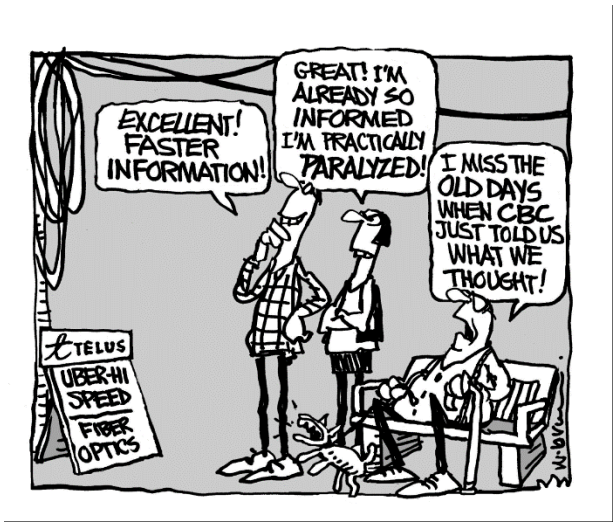
Fill the columns "used in a sentence" of the vocabulary section and the S.I. units for the physical quantities of the new concepts learnt. Add any other new words in the vocabulary section so they can be defined by next tutorial.

In a 250-500 word text apply the concept of discrete levels of energy to your specific laser/application. Using the frequency of your laser and bandgap of the material used in your application calculate the number of photons necessary for absorption. Explain in the context of your application why non-linear absorption is critical for the technique to work.

Tutorial 5 – Fibre optics vs electronics: The showdown

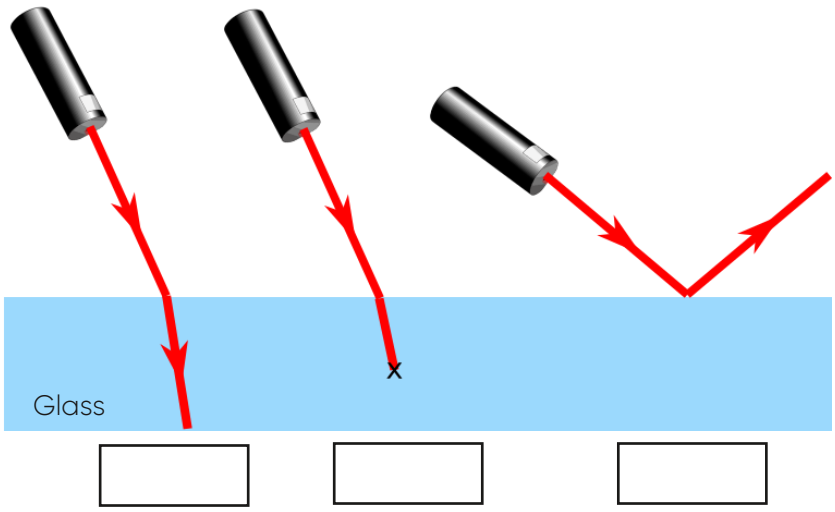
What is the Purpose of Tutorial 5?

- Use the principles of reflexion/refraction to explain how a waveguide works.
- Establish the parallelism between an electrical wire and an optical waveguide.
- Discuss the advantages of substituting electrical connections for optical, and where.



Starter- Absorption, reflection and refraction: what will you do when a surface hits you.

Fill in the boxes on the diagram bellow with the three interactions that can happen when light hits a surface: refraction/reflection/absorption.

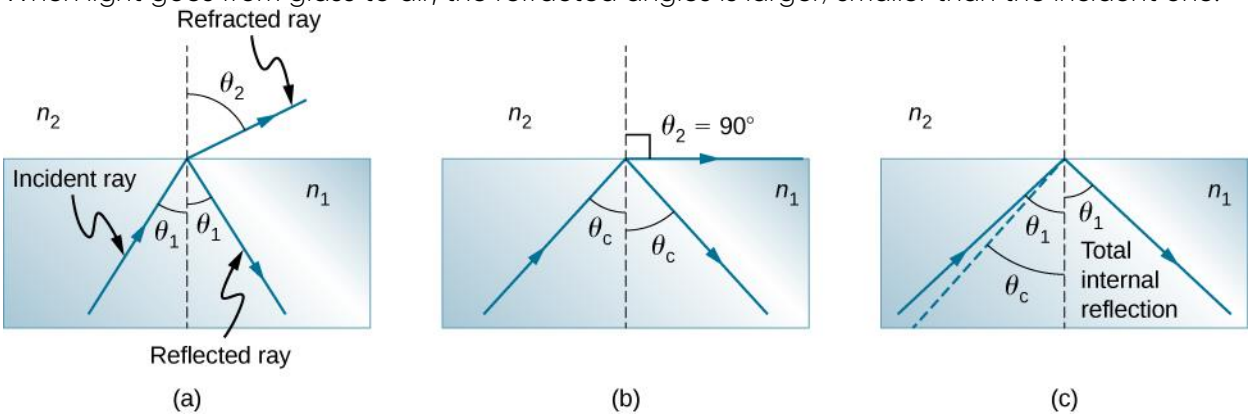


Activity I- Refraction: Bend to ascend.

The figure bellow shows the possible paths of a ray inside glass when it hits the surface at different angles.

a) Complete the following sentence:

When light goes from glass to air, the refracted angles is larger/smaller than the incident one.



b) The incident ray and refracted ray angles follow the following formula, knows as Snell's law. Complete the final box with the condition (b) in the figure, where the refracted angle is parallel with the surface.

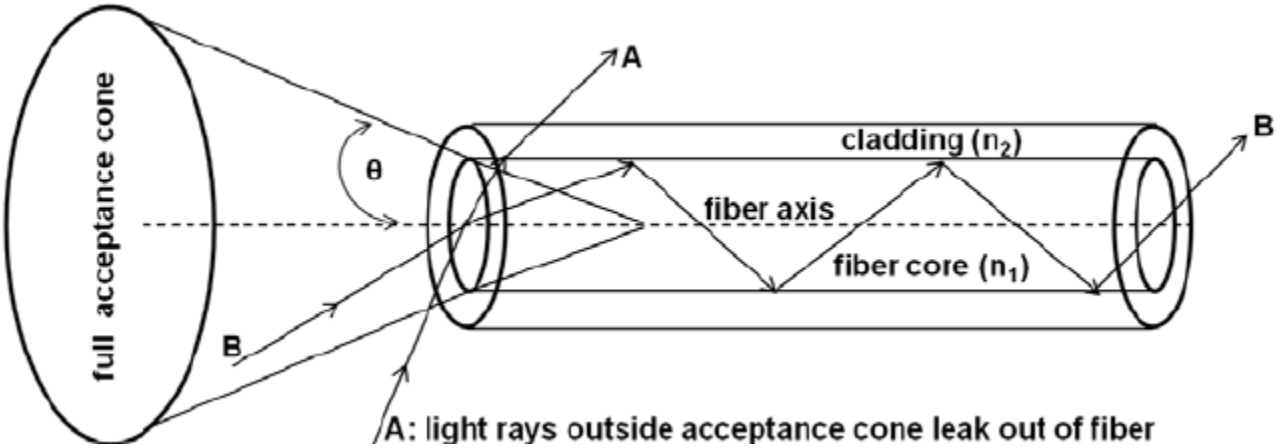
$$n_1 \times \sin\theta_1 = n_2 \times \sin\theta_2$$

$\theta_2 = 90°;\ \sin\theta_2 = 1;$ → $\theta_c =$

c) Typical glasses have a refractive index around 1.5. What is the critical angle of such a glass?

Activity II: Fibre optics: light's guiding hand.

a) Complete the following sentences bellow on how an optical fibre works



An optical fibre works based on the total _____ _____ effect as seen above. For this to work the refractive index of the fibre core need to be higher/lower than the cladding.
The other condition is that the _____ angle needs to be lower/higher than the critical angle.
In the case of a fibre this means that there is only a range of angles that are guided inside the optical fibre. Once inside, since the reflection angles are always the same/different, light can propagate without any loss to the outside.
The value of the full acceptance cone angle is equal to _____.

Challenge: what happens if you bend the fibre? Why does that happen?

Activity III- Optical fibre vs electrical cables: the final show of hands.

As we analyse in the presentation the two different technologies, annotate the differences in the table below.

	Fibre optics	Electronics
Price		
Signal capacity		

Final assignment

Write a final essay (~2000 words), where you bring together all the work done until now in the baseline assignment and homework done from the previous tutorials, presenting again your own laser fabrication system for the application that you chose. You should try to use as much as possible all the knowledge and concepts learned throughout the past tutorials to create a solid and scientific presentation.

Success criteria:

- Include content that is relevant to the topic and the specific assignment/homework title or question.
- Include key words from the glossary and demonstrate that you understand them by explaining what they mean and how they relate to the topic.
- Include research findings from a wide range of sources. As well as using the sources provided, you should be discovering some sources yourself from the independent work that you do outside tutorials.
- Give reasons and evidence to back up the points that you make. You might find the PEE structure helpful:
    - Point – make the key point clear
    - Evidence – explain the evidence for the point
    - Explanation – explain why your point is relevant and important
- Include critique, evaluation and/or response to the problem-set.
- Organise your ideas in paragraphs with a logical structure.
- Include an introduction that clearly outlines what the assignment will contain.
- Include a conclusion that summarises all the key points clearly.
- Make sure your calculations, formulas and methods are clear and structured correctly.
- Make sure that you have referenced everything correctly.
- Make sure your spelling, grammar and punctuation are accurate.
- Use a formal style of writing that is appropriate for an academic essay

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.

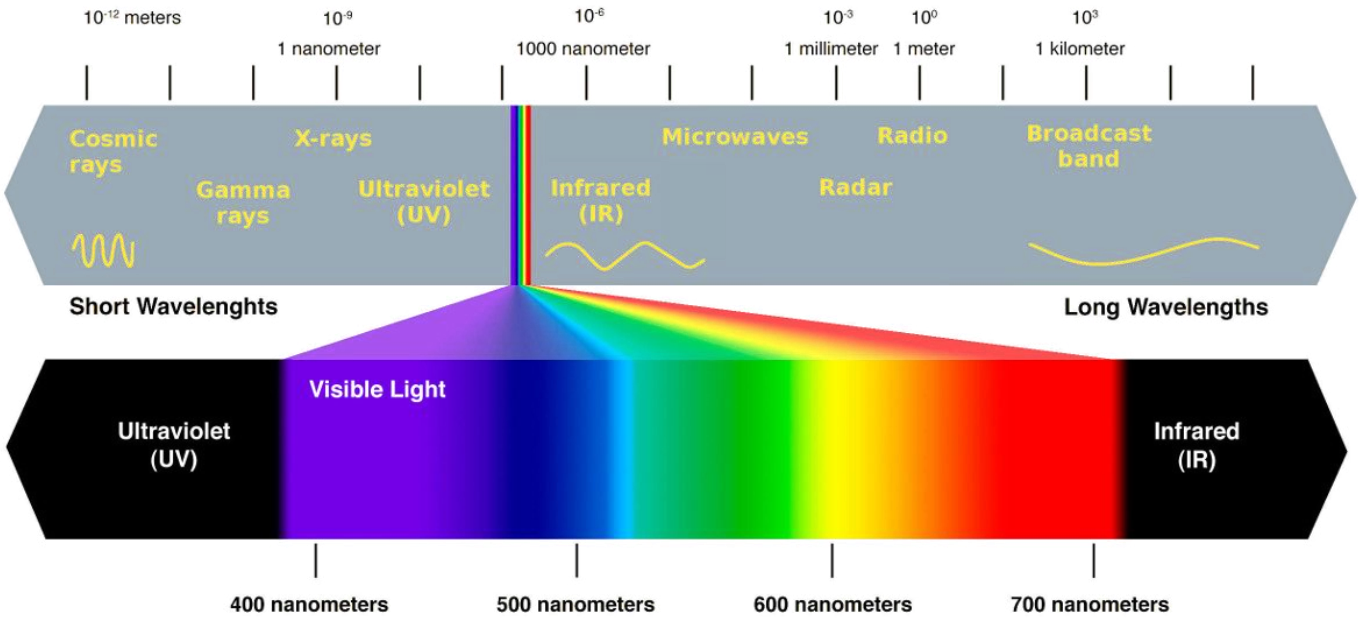
    E.g. S. Dubner and S. Levitt, (2006) *Freakonomics*, 7-9.

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

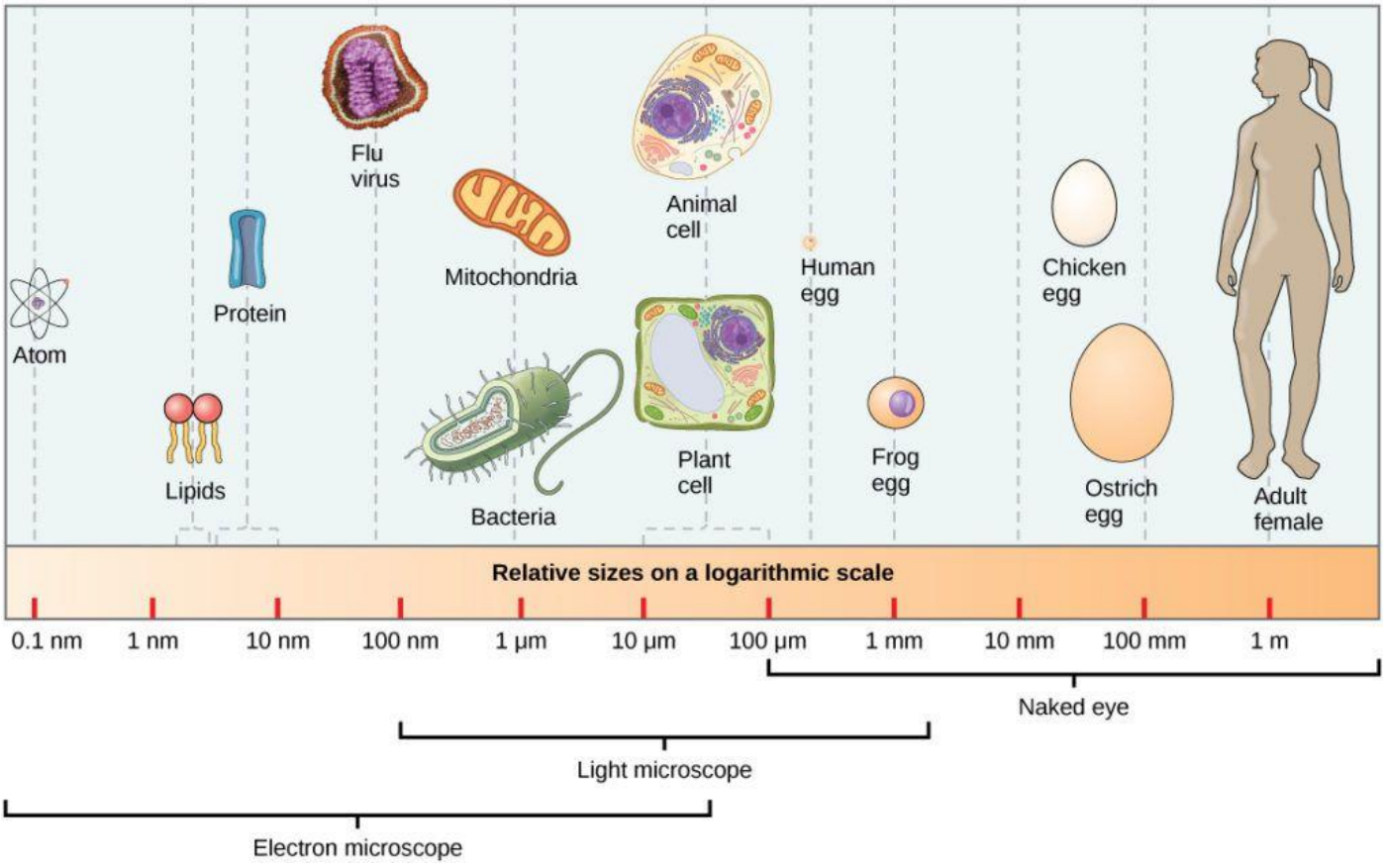
    E.g. Maev Kennedy, 'The lights to go out across the UK to mark First World War's centenary', Guardian, 10 July 2014.

Appendix 2 – General info

Electromagnetic wave spectra.



Relative sizes



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