

# Assignment 4

Choose line photons and click on the run button to watch, as many photons are sent from the left of the screen to pass through or interact with the atoms. Click on the stop button after 20 photons are sent.

Q 1) How many line photons were scattered? Repeat the demonstration with continuum photons.

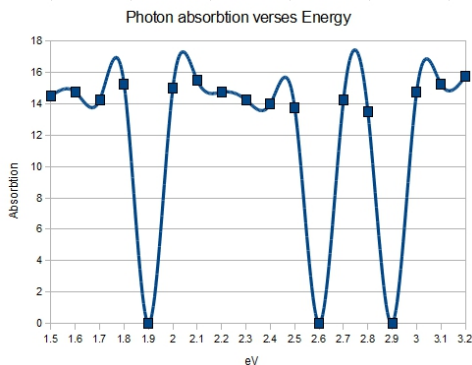
Q 2) How many continuum photons were scattered?

Q 3) Select Number of Line Photons (for "Run") from the Parameters menu and enter 20. Click on the Run button to send them through the cloud. Of the 20, what percentage were detected?

Q 4) Send 20 Continuum photons through the cloud, as you did in Exercise 2. Of the 20, what percentage were detected?

Q 5) Choose a gas by selecting Select Gas Atoms and the gas from the Parameters menu. Enter the name of the gas in Table 1. Select Change Photon Energy from the Parameters menu to set the photon energy to 1.5 eV. As you change the photon energy, the wavelength (the colour) changes automatically since the two are related. You can reset the counters and statistics using the Reset button. Be sure to reset the counters if you switch to a new gas or a different energy level.

Gas 1 Type - Hydrogen:



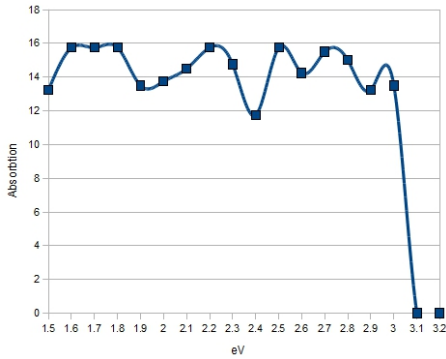
	Line (Q1)	Continuum (Q2)
Trial 1	20	4
Trial 2	20	5
Trial 3	20	3
Trial 4	19	2
Average	19.75	3.5

Trial 1	2	
Trial 2	2	
Trial 3	1	
Trial 4	1	
Average	7.5	[%]

Trial 1	17	
Trial 2	15	
Trial 3	17	
Trial 4	18	
Average	83.75	[%]

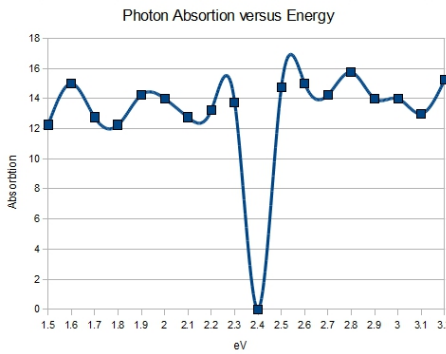
Gas 1 Type	(Hydrogen) (Q5)					
eV	Wavelength	T1	T2	T3	T4	Average
1.5	828	14	14	16	14	14.5
1.6	776	16	15	13	15	14.75
1.7	731	16	13	13	15	14.25
1.8	690	16	17	13	15	15.25
1.9	654	0	0	0	0	0
2	621	15	15	17	13	15
2.1	591	19	16	14	13	15.5
2.2	565	12	17	13	17	14.75
2.3	540	15	16	14	12	14.25
2.4	518	15	15	13	13	14
2.5	497	16	12	16	11	13.75
2.6	478	0	0	0	0	0
2.7	460	14	17	15	11	14.25
2.8	444	17	10	14	13	13.5
2.9	428	0	0	0	0	0
3	414	15	13	16	15	14.75
3.1	401	16	15	15	15	15.25
3.2	388	14	15	18	16	15.75

Q 6) Gas 2 Type - Calcium



Gas 3 Type (Calcium) (Q6a)						
eV	Wavelength	T1	T2	T3	T4	Average
1.5	828	14	12	14	13	13.25
1.6	776	19	16	14	14	15.75
1.7	731	13	16	17	17	15.75
1.8	690	15	17	15	16	15.75
1.9	654	17	12	16	9	13.5
2	621	12	12	15	16	13.75
2.1	591	15	15	11	17	14.5
2.2	565	17	13	16	17	15.75
2.3	540	15	15	15	14	14.75
2.4	518	11	14	11	11	11.75
2.5	497	19	15	12	17	15.75
2.6	478	16	13	14	14	14.25
2.7	460	15	17	13	17	15.5
2.8	444	18	13	15	14	15
2.9	428	11	15	16	11	13.25
3	414	12	14	12	16	13.5
3.1	401	0	0	0	0	0
3.2	388	0	0	0	0	0

Q 6a) Gas 3 Type - Magnesium



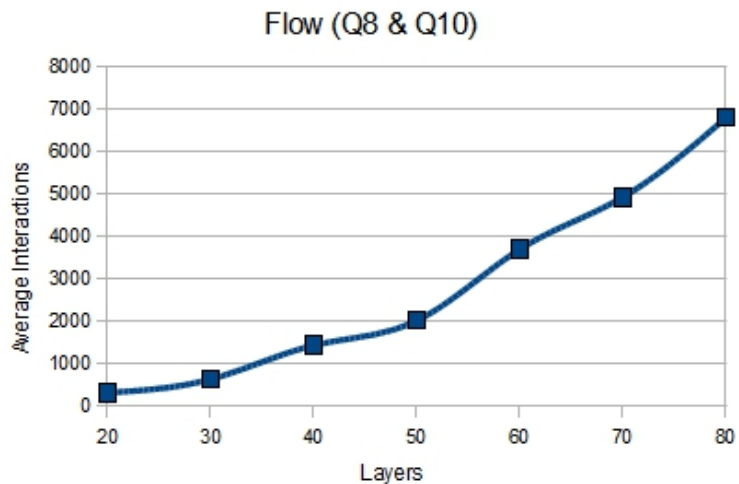
Gas 2 Type (Magnesium) (Q6)						
eV	Wavelength	T1	T2	T3	T4	Average
1.5	828	9	16	10	14	12.25
1.6	776	15	13	16	16	15
1.7	731	15	13	12	11	12.75
1.8	690	11	11	18	9	12.25
1.9	654	14	12	15	16	14.25
2	621	15	14	14	13	14
2.1	591	10	13	10	18	12.75
2.2	565	10	11	15	17	13.25
2.3	540	16	12	14	13	13.75
2.4	518	0	0	0	0	0
2.5	497	16	13	14	16	14.75
2.6	478	12	16	16	16	15
2.7	460	13	17	16	11	14.25
2.8	444	16	16	14	17	15.75
2.9	428	17	11	15	13	14
3	414	15	11	15	15	14
3.1	401	15	14	10	13	13
3.2	388	15	14	17	15	15.25

Q 7) Choose the Number of Layers in the Sun by selecting # of Layers from the Parameters menu. Run the Flow simulation with stars created with 20, 30, 40, 50, 60, and 80 layers. Repeat three times, and average each column.

Layers	20	30	40	50	60	70	80
Trial 1	299	579	794	1652	4083	6216	2612
Trial 2	186	272	1989	1380	4142	4729	3242
Trial 3	464	1045	1502	3004	2852	3812	14508
Average	316.33	632	1428.33	2012	3692.33	4919	6787.33

Q8) Plot the average results on a sheet of graph paper. The horizontal X axis should be labelled LAYERS and run from 0 on the left to 80 on the right. The vertical Y axis should be labelled AVERAGE INTERACTIONS and run from 0 at the bottom to 6500 at the top. Give your graph a title.

Q10) Sketch in a best fit line if you can.



- Q 9) Does a straight line or a curved line seem to fit your data best? and  
 Q 12) How do the calculated values of  $n^2$  compare with the average results from the simulations? If they are different, why?

From the data and subsequent graph the closest approximation is that of a straight line. The main problem seems to be that the results from the software fluctuate wildly. For instance data coming from the 80 layer star varies from 2612 to 14508. I suspect that, to get a reliable data set that reduces the significance of these huge irregularities would need many more trials than just the three asked for. Another problem seems to be that the algorithm that generates the random movement of the photon is probably linear where the relationship between the amount of mass and the length of the star's perimeter isn't. With the 2D representation of the laboratory exercise an increase of twice the area (mass) of the star represents an approximate increase in its circumference of only 41%. This would I suspect make the boundary of escape correspondingly smaller for a given mass and therefore less available. In a real star I suspect that the increase in mass would cause greater heating and therefore confer greater energy on the escaping photon. Interestingly the small data set produced does seem to agree with this proposition as it shows that stars less than 50 layers are lower than  $n^2$  whereas stars that are above 50 layers show values above  $n^2$

Q11) Complete following table

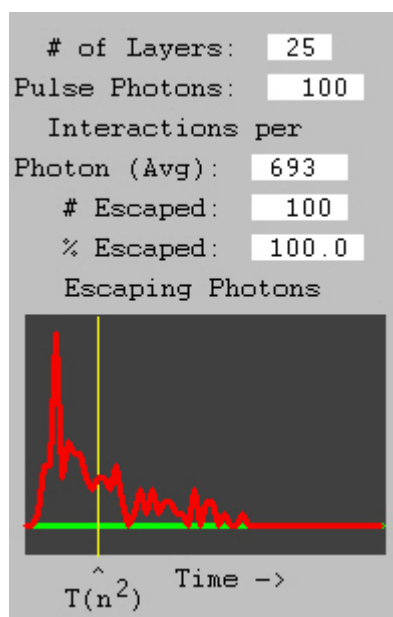
n=	20	30	40	50	60	70	80
$N^2=$	400	900	1600	2500	3600	4900	6400
Average	316.33	632	1428.33	2012	3692.33	4919	6787.33
High/Low	Low (21%)	Low (30%)	Low (11%)	Low (20%)	High (3%)	High (<1%)	High (6%)

You can simply redo one of your experiments from Exercise 5 to see how well things agree. Set the simulation for 10 photons and a 50 layer model. Then run the simulation.

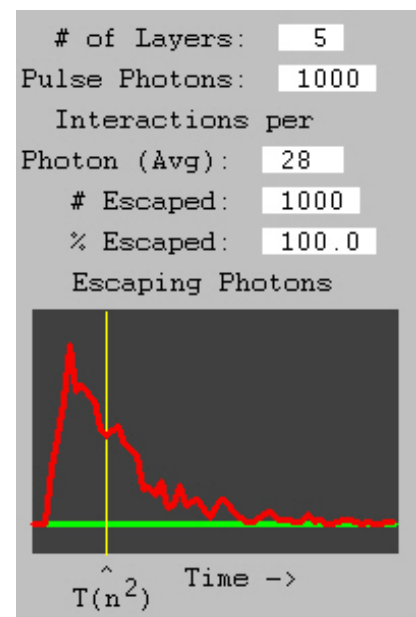
Q13) What is the average number of interactions required for a photon to reach the surface?

	#Photons	# Layers	Interactions	
Trial 1	10	50	2676	
Trial 2	10	50	3184	
Trial 3	10	50	2764	
Trial 4	10	50	2325	From Q7
Average	10	50	2737.25	2012

Q 14) To illustrate this qualitatively, set the simulation for a 25 layer star and send 100 photons out from the centre. Sketch the shape of the curve



Q 15) Try this again with a 5 layer star and 1000 photons, and sketch this curve.



Q 16) Are the two curves substantially the same shape?

While the two curves are substantially the same for instance the peak of both curves falls on the halfway line between the start and the  $T(n^2)$  line. Another similarity is where the graph approaches the zero line. The main difference in the two graphs is the width of the positive going spike and I suspect that this is a function of the relative number of photons in each of the simulations.

Q 17) In the Sun, it takes several hundred thousand years for a photon released in the core to reach the surface. Use the speed of light and the radius of the Sun to estimate the escape time for a photon from the centre of the Sun if there were no interactions.

Light Speed	Sun Radius	Time taken
300000	695500	2.32
In Km/sec	In Km	In Seconds

Q 18) Using what you have learned in this lab, explain the apparent contradiction. (~300 words)

At the heart of all main sequence stars is a nuclear reaction that fuses Hydrogen nuclei together to form Helium. This process known as *The Proton - Proton Chain* brings together, in three stages, 4 Hydrogen nuclei to form a Helium nucleus that also sees the release of a Neutrino, high energy Photons and two Hydrogen nuclei. With Photons safely on their way to the surface we turn our attention to what that journey is like.

The material at the centre of stars is a very high density plasma and this material seeks to impede photon progress to the surface. This imposition take three forms, Electron Scattering, Bound – Free Absorption and Free – Free Absorption.

**Electron Scattering:** When an electron is struck the energy of the photon is transferred in the form of vibrational or oscillating energy analogous to the ringing of a bell. This energy is re-radiated at a later stage as a photon which can be emitted in any direction.

**Bound – Free Absorption:** Happens when an atom is struck by a photon. The subsequent effect is that the extra energy causes it to eject an electron effectively ionising it. Again, as with electron scattering, when the atom reabsorbs an electron the surplus energy is re-radiated as a photon which can be emitted in any direction.

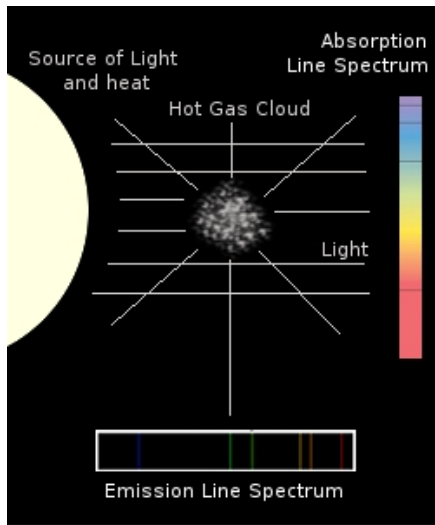
**Free – Free Absorption:** With the extremes of temperature and pressure at the core Hydrogen atoms are dissociated leaving a vast pool of free electrons which make ready targets for the high energy photons. When one of these electrons is struck it becomes more energetic this, like the other impositions, means that when it returns to its original state it re-radiates the excess energy as a photon which can be emitted in any direction.

**Important:** At no stage do photons physically slow from light speed. It is the extremely circuitous route they take from collision to collision that causes their slow progress.

Q 19) Line photons are responsible for the bright lines in an emission spectrum as well as the dark lines in an absorption spectrum. How can this one type of photon give rise to two strikingly different spectra? Write a one page essay carefully explaining how this is possible. Use diagrams if possible to clarify you argument. (~300 words)

Around the year 1857 Robert Bunsen inventor of the gas burner named after him discovered together with his colleague and fellow scientist Gustav Kirchhoff that when light from a flame contaminated with a particular element passed through a prism it produced coloured bands of light on

a dark background. These bands of light were peculiar to that element and that element alone. Kirchhoff went on in the early 1860's to formulate three laws that are named in his honour that describe the properties of both Absorption and Emission spectra.

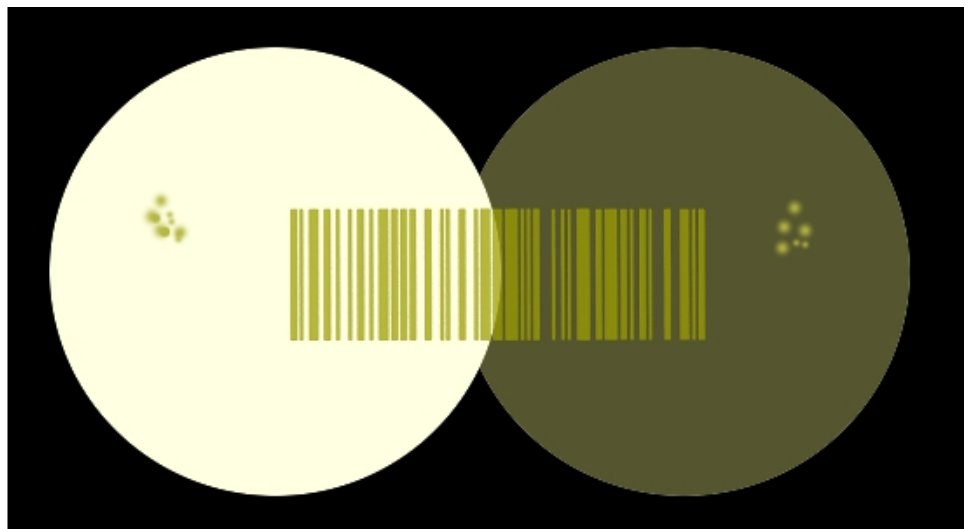


What determines the difference between an absorption and an emission spectrum has to do with the arrangement of the various features producing it. After the first law which describes how a perfect spectrum with no lines is produced his second law goes on to explain that where the heating and illuminating source is not behind the gas the elemental atoms radiate in their particular wavelength producing the bright spectral lines of emission. The third law states that where the heat source is optically in line with and behind the gas in question then the elemental atoms absorb their particular wave lengths producing an absorption spectrum.

An atom absorbing light at specific wavelengths and then re-radiating them does so in any direction. This means that, with no back lighting our point of observation must encounter some of that radiation. Set against a dark background this emission must appear

bright.

Moving our point of observation so that the heat source is behind the atom means that although it still absorbs and re-radiates at specific wavelengths it still does so in any direction. With some wavelengths streaming towards us uninhibited and others being absorbed and re-radiated, some back in the direction of the light source those spectral lines will appear dark against a bright background. A rough analogy of this are Sun Spots. Although they appear dark on the surface of the Sun they would appear very bright if the were on their own.



The central barcode is the same brightness throughout its length. It appears dark against the bright star and light against the dimmer star. The Sunspots are the same brightness on both stars. One star's spot is another's prominence

Coursework Submission Title...The Flow of Energy Out of the Sun

Tutor this work is for...Stacey Harbergham

Student Registration Number...467830

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I confirm that I am aware of the University Modular Framework Assessment Regulations (Section D Appendix C) regarding academic impropriety and that the work submitted conforms with those Regulations. I confirm that the coursework is my own and that all sources consulted have been appropriately acknowledged. I am aware that, in case of doubt, I may be required to take a viva voce examination.

Signature of Student:

Date: 25th May 2010