

9. CBRNE Coursework Q&A

Q9: Can you explain the tutorial spreadsheet?

A tutorial was held 18 Feb, which was not recorded (this was to allow students to ask questions). This included an example spreadsheet., emailed to students on 18 Feb., and available from the MSc team. Robert’s explanation of the entire spreadsheet is below. You’ll need to have the Tutorial Spreadsheet open to follow.

Energy, E (MeV)	normalised 80kV spectrum	attenuation coefficient (cm ⁻¹)							
		TNT							
1.00E-03	0.000E+00	5.536E+03							
1.00E-02	1.508E-06	6.426E+00							
2.00E-02	4.740E-02	1.047E+00							
3.00E-02	2.109E-01	5.322E-01							
4.00E-02	2.538E-01	4.023E-01							
5.00E-02	2.267E-01	3.507E-01							
6.00E-02	1.701E-01	3.240E-01							
7.00E-02	9.031E-02	3.062E-01							
8.00E-02	7.433E-04	2.937E-01							
	1.000E+00								

A9: The spreadsheet uses some data from the Coursework spreadsheet and those data are in columns A, B & C. Note that B contains the normalised X-ray spectrum, i.e., if you add up the intensity values in that column it comes to 1. Effectively the individual values indicate the fraction of the spectrum at each energy.

The diagram shows the problem that the spreadsheet solves. It consists of a piece of TNT in a cardboard box. The cardboard is thin and therefore offers no attenuation to X-rays. The orange arrows show the incident intensity and the arrows below the box show the transmitted intensity. You can see that below the TNT the arrows are smaller, therefore reduced intensity. Columns R to AB show the calculations carried out for four different X-ray beams – 30keV, 50keV, 70keV and 80kV (the spectrum). Column R is the transmitted intensity through the TNT for each energy. The calculation refers to cells S10 (incident intensity) and S11 (TNT thickness).

Note in the equation these values are ‘fixed’ by using \$S\$10 and \$S\$11 respectively. Column S (cells 14-22) is the transmitted intensity for each part of the spectrum.

Note the incident intensity at each energy is the value in \$S\$10 multiplied by the fraction of the spectrum at that energy (the numbers in column B). To obtain the total transmitted intensity of the spectrum the values in S14-S22 must be summed together (value in S23).

Having got the transmitted intensities for both the monoenergetic beams (R14-22) and the spectrum (S23) the data for the graphs can be placed in columns ready for plotting. The problem was to plot the profile 10cm either side of the edge of the TNT. These profiles have been set up in columns T to AB. T is position along the profile and the following column are the transmitted intensities without and with noise added. Noise has been added randomly between + and – one standard deviation from the transmitted intensity values. Without noise the transmitted intensities have the same values between positions 1 and 10 and another constant value between 11 and 20. With noise these values vary as would be the case in a real measurement.

Above these data the results are displayed as graphs. If you change the values in cells S10 and S11 you can see the effects in all the graphs. If you fix the intensity, as is most likely the case in a security X-ray scanner, you can find the maximum thickness of TNT that could be scanned but not noticed. For example, with incident intensity of 500, the maximum thickness is ~2-3mm.

- Q8: When using the effects such as Rayleigh and Compton for detection are you just looking at measurements on graphs or can they produce images similar to X-ray scanning?
- Q7: Can these devices be used to detect small amounts "material" that are concealed on someone's person?
- Q6: Can the scanners be small enough to employ close enough without a person or object knowing that they are being scanned for material or materials?
- Q5: I'm attempting to add random noise to the intensity at each position (question 2) but I don't think it's producing the right results.
My approach has been to take the intensity of 10^9 and +/- one standard deviation. As you've said, we're assuming Poisson and so $STDV = \sqrt{Mean} = \sqrt{Value}$ in this instance. This produces two figures, one slightly higher and one slightly lower than the original 10^9 .
I've put these through the original formula to calculate the transmitted intensity and the resulting value is the very similar to that with no noise. I have to increase to five decimal places just to see any difference in the table and plotting it on the graph shows no discernible difference between the values.
Am I taking the right approach? Are we just supposed to show the difference in a table or also plot it onto the graph?

A5:

17/02/2021

- Q4: **I think I have managed to do the first part of the coursework, but am struggling to estimate the lead thickness. Am I right in thinking I should be manipulating the equation $I = I_0 e^{-\mu x}$ somehow by using the transmitted intensity data I have from my calculations at 60 KeV for my various suitcase materials (and the data already provided for lead) ? Or should I be experimenting by playing with the data in the spreadsheet? I might be overcomplicating it as I have been looking at it for a while now.**

Grateful for any tips you can provide.

(Caveat – I last did physics and maths at GCSE level 25 years ago!).

- A4: Well done for managing the first part of the coursework. To include the Pb sheet you need to add an extra material, i.e., Pb, to your equation. So, where you have $I = I_0 \cdot \exp(-(u_1 x_1 + u_2 x_2 + \dots))$ where u_1 is the attenuation coefficient for material 1 and x_1 is its thickness, etc you will need to add an extra 'u.x' for Pb and its thickness.
You will then need to change the thickness of Pb to find the minimum value that 'hides' the threat material. To avoid retyping your equation each time you change the thickness you could use a 'fixed cell', i.e., $\$x\x , as the Pb thickness. If you're not sure how to do this look a Spreadsheet 0 that I used in Lecture 1 (this should be available to you). In that spreadsheet

column G uses cell I3 as a multiplier. Thus if I want to change all the values in column G, rather than change the equation in each cell of column G, you can just change the value in cell I3 and it affects all of column G.

16/02/2021

Q3: After doing the x-ray calculations, is it correct that noise just comes out as 0? This does make sense as the transmitted intensity is so low. If not, I will go back to the drawing board!

A3: Noise = 0 does not sound correct but it might approach zero if the transmitted intensity was very low (almost zero). The assumption that I have used in the lectures is that noise would be equal to +/- 1 standard deviation. Thus, assuming Poisson statistics where the standard deviation is the square root of the mean (if you only have one value as you do in these calculations then the mean = that value) it means the noise is given by the square root of the value. Hence the noise could only equal zero if the value was zero. For example if the value is 100 the noise would be 10 (i.e., 10%), if the value was 9 the noise would be 3 (in this case 33.3%) and if the value was 2 the noise would be $\text{SQRT}(2) \approx 1.4$ (~70%). Thus the absolute value of noise gets smaller but expressed as a percentage it gets larger. I hope this makes sense.

Q2: I am just trying to go through the CBRNE coursework and I just wanted to check I'm on the right lines as I have been struggling.

In using the $I=I_0 e^{-\mu x}$ equation I'm confused as to how the negative gets added. What I've done is as follows:

$\text{POWER}(10,9)*\text{EXP}(J73*-0.5+M73*-29.5+N73*-0.8)$ where the cells are the coefficients of the materials at the stated energy and then I've just put a negative before the thickness. Doing this appears to give me the correct shaped graph and I am able to calculate noise and do questions 1-6 but I'm concerned I've done the initial calculation wrong.

I'm also really struggling with how to do part 7 of the question, I understand which equation to use but don't know where to start. Am I right in thinking the incident intensity at any of the given energies is 80 or 150 depending on which X-ray beam is used for the calculation? So then I would pick an energy to use? Basically I don't understand what (E) is.

A2: It sounds to me that you are making good progress. Your equation is correct. You could make it a little neater by using:

$\text{POWER}(10,9)*\text{EXP}-(J73*0.5+M73*29.5+N73*0.8)$

But it will not make any difference to the answer. Remember that you need to include Pb for part 4. I'm pleased to hear you have been able to add noise and answer questions 1-5 (you say 1-6 but I think you mean 1-5?)

Question 6 is where you need to consider using an X-ray beam. The equations are basically the same but the intensity values and the attenuation coefficients change with energy. Start by using the values relevant to 1keV (row 14). In this case the intensity for the 80kV spectrum is B14 and the other materials that you are using are J14, M14 & N14, plus F14 if Pb is included. Then carry out the same calculation for rows 15 – 93 (for the 80kV spectrum) or 15-163. To carry this out the best way is to select a column, say Q, select cell Q14 and put your equation into that cell. Press 'return'. Then just 'fill down' the column, i.e. select all the

cells you want to fill (Q14-93) and press CNTRL D. This should fill all the cells 15-93 with same equation but with the values for the attenuation coefficients chosen for each energy. The total transmitted intensity, the value that a detector would detect, will be the sum of all the transmitted intensities at all the energies (1-80keV or 1-150keV) you have just calculated. Hence, sum the values in the column to give you the transmitted intensity.

In answer to your question, what does (E) mean – it means the quantity in front of (E) depends upon energy, i.e. $I(E)$ means that the intensity depends upon, or changes, with energy. Thus in the case of the X-ray spectrum (column B or C) you will notice that the intensity values change with energy.

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Q1: Help with coursework please, I assume we have to start with the equation -

$$I=I_0 e^{-\mu x}$$

That is far as I can get - how do you place that equation into excel? Or is that not it?

A1: Yes, you're using the right equation. To set up that equation in Excel you need to select the cell where you want the answer, press '=' and then enter the equation. Having entered the equation press 'return' and the answer will be in the selected cell. Remember to put the multiplication sign (*) between anything that needs to be multiplied. To create ' $e^{-\mu x}$ ' where ' μ ' is the attenuation coefficient you should use the exponential function built into Excel, i.e., exp(...).

You might find it helpful to look at Spreadsheet 0 that I used in the first lecture. It should be available to you. That spreadsheet has several equations within it. For example, cell G6 has an equation and also uses the idea of fixing a given cell by the use of '\$x\$y'. The fixed cell allows you to multiply a column of data by the same number and should you wish to change that number you only need to change the one cell rather than change the number for each member of the column.