ADVANCED CONNECTIONS | CYSYLLTIADAU PELLACH

SESSION PLAN

Physics Tutorial 5: Functioning Like a Physicist

Aim

To understand how logarithms and exponentials are used in physics

Learning Objectives

By the end of this session, the mentees will be able to...

- Describe exponential decay/growth and recognise it on a graph
- Explain the random nature of exponential decay
- Recognise the different elements of the exponential decay equation, and their equivalents in real-life examples

Prepare in Advance

- There shouldn't be anything to prepare in advance, just have a read through the answers and make sure you understand and can explain them!
- If you want to do the exam questions, you will need to look through the answers ahead of time.

Scaffolding

If a mentee finishes early:

- Get them to try the optional extras (if they haven't already)
- Challenge them to complete the exam questions on the PPT

If a mentee is struggling:

- Pair them with another mentee who can help explain
- Show them the exponential decay graphs, and explain the easiest way to tell is by seeing how long it takes to change by half. If it takes the same amount of time to halve, it's exponential!

Session Flow

Time	Activity
5 min	**Introduction** • Run through the aim and LOs • Recap the ground rules if needed
15 min	**Self-study Recap** • Go through the self-study materials and any solutions (on next page) • Answer any questions the mentees may have about the materials
10 min	**Exponential Graphs** • Discuss exponential decay/growth and how we can check whether graphs are showing exponential trends
25 min	**Radioactive Dice!** • Use the dice simulator to demonstrate exponential decay ◦ You can share this spreadsheet with mentees if you want them to have a go! • Discuss the questions on the PPT • Watch the beer video and discuss the questions on the PPT
5 min	**Plenary** • Allow some time for mentees to ask questions and discuss today's topic

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MENTOR GUIDANCE

SESSION 5: FUNCTIONING LIKE A PHYSICIST

PART 1: SELF-STUDY RECAP

This first half of this tutorial is going through the self-study materials to ensure that mentees understand what uncertainty is, why we use it, and how to calculate it.

TASK 1:

The answer is A. This is because it's increasing by the same intervals each time rather than the same **factor.**

TASK 2:

REMEMBER THE LOG RULES

1. $\log(a) + \log(b) = \log(ab)$
2. $\log(a) - \log(b) = \log\left(\frac{a}{b}\right)$
3. IF $y = A^x$ THEN $\log_A(y) = x$
4. $\ln(e^x) = x$

1. $\log_{10}(x) + \log_{10}(50) = 3$

$$\log_{10}(50x) = 3$$

$$50x = 10^3$$

$$x = \frac{10^3}{50}$$

$$x = 20$$

2. $\log_x(64) = 6$

$$64 = x^6$$

$$x = 64^{\frac{1}{6}}$$

$$x = 2$$

Mentees should know how to re-arrange powers

3. $e^x = 20$

$$\log_e(20) = x$$

$$x = \ln(20)$$

$$x = 3.00$$

Using the reverse of Rule 3 above!

Mentees may have stopped at "ln(20)"

Rounded to 3 sig. fig. - mentees might have "2.9957..."

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TASK 3:

A $Q = Q_0 e^{\frac{-t}{RC}}$ RE-ARRANGE TO GET $\frac{Q}{Q_0} = e^{\frac{-t}{RC}}$

TAKE LN OF BOTH SIDES $\ln\left(\frac{Q}{Q_0}\right) = \ln\left(e^{\frac{-t}{RC}}\right)$ USING RULE 4 $\ln\left(\frac{Q}{Q_0}\right) = \frac{-t}{RC}$

WE CAN FLIP THE LN TO REMOVE THE - $\ln\left(\frac{Q_0}{Q}\right) = \frac{t}{RC}$ AND SO $t = RC\ln\left(\frac{Q_0}{Q}\right)$

B $N = N_0 e^{-\lambda t}$

USE THE SAME METHOD AS ABOVE TO GET $t = \lambda \ln\left(\frac{N_0}{N}\right)$

OPTIONAL EXTRAS

$\beta = 10log_{10}\left(\frac{I}{I_0}\right)$ RE-ARRANGE TO GET $I = I_0 10^{\frac{\beta}{10}}$

$$I_{conversation} = 10^{-12}10^{\frac{60}{10}} = 0.000001 = 1 \times 10^{-5} dB$$

$$I_{jet} = 10^{-12}10^{\frac{140}{10}} = 100 = 1 \times 10^{2} dB$$

So, a jet taking off 30 metres away is **100 million times louder** than a conversation!!

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OPTIONAL

EXAM PRACTICE

All formulae/constants are given in mentees' data booklets during exams

1. (a) There are two methods you could use to get the marks:

USING DECAY CONSTANT

$$\lambda = \frac{\ln(2)}{T_{\frac{1}{2}}} = \frac{\ln(2)}{3.8} day^{-1}$$ **1 mark**

$$\lambda = 0.182 day^{-1}$$

So, activity after 12 days is:

$$A = A_0 e^{-\frac{12\ln(2)}{3.8}}$$ **1 mark**

$$A = 0.112 A_0$$ **1 mark**

OR

USING HALF-LIFE

Number of half-lives in 12 days is:

$$n = \frac{12}{3.8} = 3.16$$ **1 mark**

So, the fraction after 12 days would be:

$$2^{-3.16} = 0.112$$

1 mark **1 mark**

So, the percentage reduction is 88.8% 1 mark

1. (b) Any four from:

- Counts per minute is reduced significantly / almost by half (or equivalent) by the paper, so **alpha** radiation is present
- Most of the remaining radiation is stopped / counts per minute reduces again by the aluminium, so **beta** radiation is present
- The count for lead is similar to aluminium, so **no gamma** radiation is present
- The measured counts with aluminium and lead are basically the same, so the **background radiation** is ~25 counts per minute
- The increased value for lead is because of the **randomness** of nuclear decay

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OPTIONAL

EXAM PRACTICE

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2. (a) (i) There are two methods you could use to get the marks:

IN DAYS

$$\lambda = \frac{\ln(2)}{T_{\frac{1}{2}}} = \frac{\ln(2)}{11.4 \times 24 \times 60 \times 60}$$

1 mark

SO

$$\lambda = 7.037 \times 10^{-7} s^{-1}$$

1 mark

OR

IN SECONDS

$$\lambda = \frac{\ln(2)}{T_{\frac{1}{2}}} = \frac{\ln(2)}{11.4}$$

1 mark

SO

$$\lambda = 0.0608 days^{-1}$$

1 mark

must have units to get second mark

2. (a) (ii) There are two methods you could use to get the marks:

USING HALF LIFE

No. of half lives that have occurred at 57 days is:

$$x = \frac{57}{11.4} = 5 \text{ half lives}$$

1 mark

SO

$$A = \frac{A_0}{2^x} = \frac{A_0}{2^5}$$

OR

USING DECAY EQUATION

$$A = A_0 e^{-\lambda t}$$

$A =$ what we're calculating
$A_0 =$ we leave the answer in terms of this
$\lambda = \frac{ln(2)}{T_{\frac{1}{2}}}$ $t = 5T_{\frac{1}{2}}$

SO

$$\lambda t = \frac{ln(2)}{T_{\frac{1}{2}}} \times 5T_{\frac{1}{2}} = 5\ln(2)$$

1 mark

Substitute this in: $A = A_0 e^{-5\ln(2)} = \frac{1}{2^5} A_0$

$$A = \frac{1}{32} A_0$$

1 mark

2. (a) (iii) The number of particles remaining after 57 days is: $N = \frac{1}{32} N_0$ **1 mark**

So, the decrease in the number of nuclei would be: $\left(1 - \frac{1}{32}\right) N_0$ **1 mark**

The **percentage** decrease would be: $\frac{\left(1 - \frac{1}{32}\right) N_0}{N_0} \times 100 = 96.875\%$ **1 mark**

3% gets 2 marks

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PART 2: SKILLS PRACTICE

The second half of this tutorial gives students an opportunity to practice their skills and ask any questions.

EXPONENTIAL GRAPHS

10 MINS

EXPONENTIAL DECAY

Which of the graphs shows exponential decay? Get the mentees to type their answer in the chat (and include **why**) and press send together. Discuss how they could check which graphs are exponential, then use the animations on the PPT to show how this is done.

EXPONENTIAL GROWTH

Do the same again with the growth graphs on the next slide.

What each type of graph actually is can be found in the PPT notes!

RADIOACTIVE DECAY

25 MINS

Emphasise the formula for exponential decay:

$$N = N_0 e^{-\lambda t}$$

$N =$ amount of stuff at time t
$N_0 =$ amount of stuff at t=0
$\lambda =$ decay constant
$t =$ time

Use the spreadsheet named **"Dice Simulator"** for this activity and share your screen. At the top of the spreadsheet, you can input:

number of dice at the start (equivalent to N_0)
how many sides the die has (equivalent to t)
how many sides count as "decay" (equivalent to λ)

- **What does a single die represent at the different points?** One die is a radioactive atom.
- **Why do we get more reliable graphs with 1,000 dice rolls compared to 100?**

  Because of the random nature of decay, we are likely to get better results when we use larger numbers in our samples.
- **Predict the shape the graph would be if they were 20-sided dice.**

  It will take longer to decay, because the chance of decay is lower (1/20 instead of 1/6).
- **Predict the shape of the graph if they were 6-sided dice, but a 4, 5, or 6 counted as a decay.**
  - **Why does this graph show exponential decay?**

  Increasing the decay constant (how many sides count as decay) will decrease the half-life, because there is a higher chance of decay (1/2 instead of 1/6).

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RADIOACTIVE BEER DECAY VIDEO

4 MIN VIDEO

If you have issues watching the video, you can just send the link through to the mentees and ask them to put and emoji in the chat after they have watched it: https://www.youtube.com/watch?v=rbhU8Fand2k

Discuss the mentees' answers to the questions after the video.

- **Why do we not just measure the height of the bubbles?**
  The height of the bubbles won't change!
- **Why do we wait for a couple of minutes at the end?**
  The increase every 10 seconds is no longer visible as they're so close together, but we want to record the final beer height so will allow a longer time gap for the final recording.
- **What could affect the speed at which the bubbles pop?**
  e.g. how the beer is poured, how many bubbles there are, etc.
- **What assumptions are we making?**
  e.g. that the bubbles are popping randomly, etc.

TOP TIPS

- Emphasise to the mentees that the equations on their pre-tutorial materials for capacitance and radioactive decay are **analogous** - they both use the same equation, but with different constants!
- If you finish early, you can try some of the exam questions on the PPT.
  - Answers here: https://www.ocr.org.uk/Images/58216-mark-scheme-unit-g485-fields-particles-and-frontiers-of-physics-january.pdf
  - Mentees may be keen to try exam questions ahead of their exams, so you can do this instead of the beer radioactivity video if you like.
- If you have a specialism/interest in a related field (e.g. radiology, nuclear waste management, radiation defence in space settlement construction, nuclear weapons, etc.). then bring this into the tutorial!

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PHYSICS TUTORIAL XX: XXX LIKE A PHYSICIST

BRIGHT IDEAS!

This page contains ideas for alternative sessions, changes/additions, extra activities, etc.
Feel free to use as you wish!

Radioactivity Everywhere

You could challenge mentees to think of various careers and situations where radioactivity is used (there's a lot for this one!). Some examples:

- Engineering and construction: health and safety, power plants
- Biology and chemistry: radiology, nuclear chemistry,
- Physics (of course!): astrophysics (designing space settlements to withstand radiation), weapons and defence, nuclear industry

Physics Skills

If you think the mentees are struggling to link the topic to wider skill applications, you can run an activity where they list the skills they use to solve the problems, and then discuss where they use those skills in physics.

Radioactive Dating Game

You could use Colorado University's interactive Radioactive Dating Game:
https://phet.colorado.edu/en/simulations/radioactive-dating-game

This can be run on a browser or downloaded. There are various activity ideas on the website!

Radioactive Materials

If mentees are interested in the environmental impact of radioactive materials, you could design a session based around nuclear waste/radioactive material protection, etc.