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SESSION PLAN

Physics Tutorial 2: Performing Like a Physicist

Aim

To understand what standard form is, and how it is used to express very large or small values in physics

Learning Objectives

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

- Explain when and why physicists use standard form
- Perform basic calculations using standard form
- Recognise the difference between accuracy and precision, and how they are used in physics

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!

Scaffolding

If a mentee finishes early:

- Get them to try the optional extras (if they haven't already)
- Get them to think of another "million pound question" about a physics topic of their choice

If a mentee is struggling to calculate using standard form:

- Talk them through it step-by-step (e.g. "are you multiplying or dividing?" "what is the rule you need to use?"

If a mentee is struggling to think of a "million pound question":

- Allow them to choose any physics topic instead of just from this session
- Show them some example questions

Session Flow

Time	Activity
5 min	**Introduction** • Run through the aim and LOs • Recap the ground rules if needed
20 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	**Who Wants to Be a Millionaire?** • Explain the millionaire cheating story and explain that mentees could have answered it • Challenge mentees to create their own "million pound question" ◦ Mentees can work in pairs or threes in the mini breakout rooms if they want to
20 min	**Quiz Time!** • Gather the mentees' questions and do a short millionaire quiz!
5 min	**Plenary: Topic Discussion** • Allow some time for mentees to ask questions and discuss today's topic

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MENTOR GUIDANCE

SESSION 2: PERFORMING 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 standard form is, why we use it, and how to calculate with it.

TASK 1: CALCULATION PRACTICE

1. $(3 \times 10^4) \times (8 \times 10^2)$

$= (3 \times 8) \times (10^4 \times 10^2)$

$= 24 \times 10^{4+2}$

$= 24 \times 10^6$

$= 2.4 \times 10^7$

Mentees may forget to convert so it's between 0 and 10

2. $\dfrac{(8.4 \times 10^6)}{(2.1 \times 10^2)}$

$= (8.4 \div 2.1) \times (10^6 \div 10^2)$

$= 4 \times 10^{6-2}$

$= 4 \times 10^4$

3. $(9 \times 10^2) \times \dfrac{(5 \times 10^9)}{(2.5 \times 10^3)}$

$= (9 \times 10^2) \times ((5 \div 2.5) \times (10^9 \div 10^3))$

$= (9 \times 10^2) \times (2 \times 10^{9-3})$

$= (9 \times 10^2) \times (2 \times 10^6)$

$= (9 \times 2) \times (10^2 \times 10^6)$

$= 18 \times 10^{2+6}$

$= 18 \times 10^8$

$= 1.8 \times 10^9$

4. $(5 \times 10^6) \times \dfrac{2.4 \times 10^2}{1.2 \times 10^8} = 10$

$= (5 \times 10^6) \times ((2.4 \div 1.2) \times (10^2 \div 10^8))$

$= (5 \times 10^6) \times (2 \times 10^{2-8})$

$= (5 \times 10^6) \times (2 \times 10^{-6})$

$= (5 \times 2) \times (10^6 \times 10^{-6})$

$= 10 \times 10^{6-6}$

$= 10 \times 10^0$

$= 10$

5. $\dfrac{10^3 \times 10^{-2} \times 10^7}{10^{-5} \times 10^4} = 10^9$

$= (10^{3-2+7}) \div (10^{-5+4})$

$= (10^8) \div (10^{-1})$

$= 10^{8--1}$

$= 10^9$

Mentees may not have tried the harder ones (4 and 5)

COMMON PROBLEMS

Mentees might:

- Forget that the value has to be between 0 and 10, so may not convert (e.g. from 24 to 2.4) - they might also forget to change the power when they do
- Be confused by the different format in Q4-5 (10^B instead of A x 10^B). You can explain that this is the same as writing 1 x 10^B in a shorter form

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TASK 2: GRAVITY

$G = 6.67 \times 10^{-11}$ Nm²/kg²
$m_1 = 5.97 \times 10^{24}$ kg
$m_2 = 7.34 \times 10^{22}$ kg
$r = 3.85 \times 10^{8}$ m

There are **two correct methods** to solve this. We've included both here:

$$F = \frac{Gm_1m_2}{r^2} = \left(\left(6.67 \times 10^{-11}\right) \times \left(5.97 \times 10^{24}\right) \times \left(7.34 \times 10^{22}\right)\right) \div \left(3.85 \times 10^{8}\right)$$

$$= \left(\left(6.67 \times 5.97 \times 7.34\right) \times \left(10^{-11} \times 10^{24} \times 10^{22}\right) \div \left(3.85 \times 10^{8}\right)$$

$$= \left(292.28 \times 10^{35}\right) \div \left(3.85 \times 10^{8}\right) \quad \textbf{OR} \quad = \left(2.92 \times 10^{37}\right) \div \left(3.85 \times 10^{8}\right)$$

$$= \left(292.28 \div 3.85\right) \times \left(10^{35} \div 10^{8}\right) \qquad = \left(2.92 \div 3.85\right) \times \left(10^{37} \div 10^{8}\right)$$

$$= 75.9 \times 10^{27} \qquad = 0.759 \times 10^{29}$$

$$= 7.59 \times 10^{28} \qquad = 7.59 \times 10^{28}$$

TASK 3: ACCURACY VS PRECISION

The idea of this exercise is to get mentees to consider what accuracy and precision are in the context of a real experiment. Mentees might suggest the following things:

HIGH ACCURACY

- A **radio-controlled** clock is accurate to the actual time

LOW ACCURACY

- **Human error** of the person taking the time is not very accurate
- The **horizon being obscured** makes the dawn time measured less accurate
- What way is their window facing? This will make the measurement less accurate to **actual dawn time**

HIGH PRECISION

- Measuring to the nearest **100 ms** makes the experiment more precise
- The physicist is performing the experiment **every day,** so if they do it lots of times their measurements will be precise

LOW PRECISION

- **Human error** also makes the time less precise - they are measuring when the light reaches their room and taking the time by eye

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TASK 4: RECORDING DATA

Mentees are asked to find **at least 3,** but there are quite a few errors in the table. They're all pointed out here:

T has no units

What do T, RC and RTh mean? An outside observer wouldn't know

Voltage (V)	T	RC (Ω)	RTh (Ω)
6.28	293.2	227.4	13100
6.088	286.4	223	16440
5.8	276.7	217.2	22600
5.1	252.7	201	56270
5	249.2	198.9	64660
4.35	226.9	184.4	175900
4.0	216.9	177.7	284100
3.9119	211.7	174	372000
3.5	200.4	165.8	704000
3.0809	183.2	153.4	2055000
2.245	161.2	135.6	10600000
1.952	144.4	121.2	49400000
1.6	134.4	110.1	OL

Voltage is not recorded with consistent sig figs (mentees might say "to a decimal place")

RTh would be better presented in standard form

What does "OL" mean? An outside observer wouldn't know

RC is also not recorded with consistent sig figs

OPTIONAL EXTRAS

1. $E = mc^2$

$= (9.11 \times 10^{-31}) \times (2.99 \times 10^{8})^2$

$= (9.11 \times 10^{-31}) \times (2.99 \times 10^{16})$

$= (9.11 \times 2.99) \times (10^{-31} \times 10^{16})$

$= 27.24 \times 10^{-15}$

$= 2.72 \times 10^{-14}$

$m_e = 9.11 \times 10^{-31}$ kg
$c = 2.99 \times 10^{8}$ m/s

2. $$E = \frac{Q}{4\pi\varepsilon_0 r^2}$$

$Q = 3.20 \times 10^{-16}$ C
$\varepsilon_0 = 8.85 \times 10^{-12}$ F/m
$r = 2.4$ nm

$= (3.20 \times 10^{-16}) \div \left(4\pi \times (8.85 \times 10^{-12}) \times (2.4 \times 10^{-9})^2\right)$

$= (3.20 \times 10^{-16}) \div (4\pi \times (8.85 \times 10^{-12}) \times (2.4 \times 10^{-18}))$

$= (3.20 \times 10^{-16}) \div (4\pi \times (8.85 \times 2.4) \times (10^{-12-18}))$

$= (3.20 \times 10^{-16}) \div (4\pi \times (21.24 \times 10^{-30}))$

$= (3.20 \times 10^{-16}) \div (266.91 \times 10^{-30})$

$= (3.20 \div 266.91) \times \left(10^{-16} \div 10^{-30}\right)$

$= 0.0120 \times 10^{14}$

$= 1.20 \times 10^{12}$

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OPTIONAL

EXAM PRACTICE

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

1. (a) (i) Use of either: $pV = \frac{1}{3}Nm\overline{c^2}$ **OR** $p = \frac{1}{3}\rho\overline{c^2}$ **1 mark**

Mentees can either re-arrange first then substitute values, or sub values then re-arrange:

$$c = \sqrt{\frac{3pV}{Nm}}$$

$$c = \sqrt{\frac{3 \times 3 \times 10^5 \times 2.14 \times 10^{-6}}{1.70 \times 10^{20} \times 1.39 \times 10^{-25}}}$$

1 mark

$$c = \sqrt{\frac{3p}{\rho}}$$

$$\rho = \frac{m}{V} = 11.04 \text{ kg/m}^3$$

1 mark

$$c = \sqrt{\frac{3 \times 3 \times 10^5}{11.04}}$$

$V = 2.14 \times 10^{-6}\text{ m}^3$
$p = 300 \text{ kPa} = 3 \times 10^{5} \text{ N/m}$
$N = 1.70 \times 10^{20}$ molecules
$m_{molecule} = 1.39 \times 10^{-25}$ kg
$m_{total} = 2.36 \times 10^{-5}$ kg

$$c = 286 \text{ m/s}$$ **1 mark**

(a) (ii)

This is a tricky one. There are a few methods that get you the right answer. The most elegant one is to divide the molecular mass, $m_{molecule}$ by the unified atomic mass unit, u:

$$RMM = \frac{m_{molecule}}{1u} = \frac{1.39 \times 10^{-25}}{1.66 \times 10^{-27}} = 84$$

1 mark (method) **1 mark** (answer)

Mentees get 1 mark for method and 1 mark for answer

(a) (iii)

Use of: $pV = nRT$ **1 mark**

$n =$ No. of moles of the gas, which is calculated by dividing the number of molecules by the Avogadro constant

$$n = \frac{1.7 \times 10^{20}}{6.02 \times 10^{23}} = 2.82 \times 10^{-4} \text{ moles}$$

1 mark

$$T = \frac{pV}{nR} = \frac{3 \times 10^5 \times 2.14 \times 10^{-6}}{2.82 \times 10^{-4} \times 8.31} = 275 \text{ K}$$ **1 mark**

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OPTIONAL

EXAM PRACTICE CONT.

2. (a) (i) Use of: $g = -\frac{GM}{r^2}$

It's negative because it's going in towards the planet!

$G = 6.67 \times 10^{-11}\ \text{Nm}^2\text{kg}^{-2}$
$M = 1.99 \times 10^{30}\ \text{kg}$
$r = 1.50 \times 10^{11}\ \text{m}$

1 mark *for formula and substitution*

$$g = -\frac{6.67 \times 10^{-11} \times 1.99 \times 10^{30}}{\left(1.50 \times 10^{11}\right)^2}$$

$$= -5.90 \times 10^{-3}\ \text{N/kg}$$

1 mark
must have units for second mark, negative not necessary

(a) (ii) Use of: $V_g = -\frac{GM}{r}$

$$V_g = -\frac{6.67 \times 10^{-11} \times 1.99 \times 10^{30}}{1.50 \times 10^{11}} = -8.85 \times 10^{8}\ \text{J/kg}$$

1 mark *for formula and substitution*

1 mark
must have negative sign for second mark

(b)

Use of: $r_1 = \frac{M_2}{M_1 + M_2} d$ **1 mark**

$M_1 = M_{sun} = 1.99 \times 10^{30}\ \text{kg}$
$M_2 = M_{jupiter} = 1.90 \times 10^{27}\ \text{kg}$
$d = 7.79 \times 10^{11}\ \text{m}$

$$r_1 = \frac{1.90 \times 10^{27}}{1.99 \times 10^{30} + 1.90 \times 10^{27}} \times 7.79 \times 10^{11} = 7.43 \times 10^{8}\ \text{m}$$ **1 mark**

7.43×10^{8} is more than the radius of the Sun (6.96×10^{8}), so the centre of mass is outside the Sun

1 mark

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PART 2: SKILLS PRACTICE

The second half of this tutorial gives students an opportunity to practice their skills and take part in a quiz.

WHO WANTS TO BE A MILLIONAIRE?

In 2001, a man cheated his way to winning Who Wants to be a Millionaire: https://www.youtube.com/watch?v=HIGtLRnGCD4 *(5 mins)*

- The million pound question was...

A number one followed by one hundred zeros is known by what name?

It's about prefixes!!

GOOGOL — MEGATRON

GIGABIT — NANOMOLE

Your mentees would have got the million pound question correct! They know that mega has 6 zeroes, giga has 9 zeroes, and nano has 9 zeroes after the decimal place. So it's got to be a Googol.

Give the mentees 5-10 minutes to **come up with their own "million pound question"** about this session's topics. Mentees can work in pairs/threes in the mini breakout rooms, or on their own. **Make sure they create 1 question with 4 multiple choice answers.**

After the time is up, bring mentees back to the main room and ask them to **privately** message you their question and choices in the Zoom chat (don't forget to get the correct answer from them too!).

Put the questions into the template on the PPT, then quiz the mentees and see how many they can get correct.

You could add a competitive element with 1st, 2nd and 3rd places!

TOP TIPS

- If mentees complete their question early, you can add their questions as you go to save time.
- Mentees might get stuck. Encourage them to work together, or use some of the examples on the PPT to give them inspiration.
  - If they're really stuck, you could get them to make a question about any physics topic of their choice.

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BRIGHT IDEAS!

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

Standard Form Everywhere

You could include examples of where standard form is useful in various careers and situations. Some examples:

- Engineering and construction: large structures, bridges, roads
- Architecture: maths is used throughout architecture
- Biology and chemistry: microscopic level, molecules
- Finances: large companies, revenue
- Physics (of course!): astronomy, semiconductors

Did you know that engineering has it's own standard form notation called "engineering form"?

Physics Skills

If you think the mentees are struggling to link the topics 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.

Star Wars Standard Form

If mentees are struggling with standard form calculations, try this activity.

The Millenium Falcon flies at the speed of sound normally, and flies at the speed of light when it goes into hyperdrive.

Calculate how long these journeys would take the Millenium Falcon (answers in standard form!)

speed of sound = 3.40×10^2 m/s
speed of light = 2.99×10^8 m/s

From	To	Distance (km)	Hyper drive?	Time Taken (s)
Hoth	Naboo	1.224×10^7	NO	??
Tatooine	Dagobath	3.06×10^6	NO	??
Endor	Ord Mantell	1.35×10^{13}	YES	??
Dantooine	Kashyyk	??	NO	1.2×10^4
Bespin	Kessei	??	YES	7.5×10^3