ADVANCED CONNECTIONS | CYSYLLTIADAU PELLACH

PRE-TUTORIAL MATERIAL
SESSION 2: PERFORMING LIKE A PHYSICIST

The aim of this tutorial is to consider how we think about expressing and analysing values and measurements. More specifically, using standard form to express values, and using accuracy and precision to scrutinise them.

WHAT IS STANDARD FORM?
AND WHY DO WE USE IT?

In physics, we deal with a lot of very large numbers and a lot of very small numbers. Writing these numbers out in full is time-consuming, makes calculations unnecessarily difficult, and it's not immediately obvious how big or small these values are. Instead, we use **standard form:**

$$A \times 10^B$$

$1 \leq A < 10$ — A will always be a number between 1 and 9 *(never double digits)*

B is called the **order of magnitude**

Using this form to express orders of magnitude is so useful that physicists do it all the time! If you've ever used **milli**metres (**m**m), **kilo**grams (**k**g), or **mega**bytes (**M**B) then you might have done this without even realising. The prefixes **m, k,** and **M** simply correspond to a **standard form** (also known as a "power of 10").

Prefix	Symbol	Standard Form
Tera	T	10^{12}
Giga	G	10^{9}
Mega	M	10^{6}
Kilo	k	10^{3}
Milli	m	10^{-3}
Micro	μ	10^{-6}
Nano	n	10^{-9}
Pico	P	10^{-12}

EXAMPLE: GRAVITY

Let's say we wanted to find the gravitational force between the Earth and the Moon according to this equation:

$$F = \frac{Gm_1m_2}{r^2}$$

where

$G = 0.0000000000667$ Nm²/kg²
$m_1 = 5970000000000000000000000$ kg
$m_2 = 73400000000000000000000$ kg
$r = 385000000$ m

In standard form, we would write these as:

$G = 6.67 \times 10^{-11}$ 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

MUCH EASIER TO READ!

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CALCULATIONS USING STANDARD FORM

We use these rules when multiplying or dividing values in standard form:

$$A^x \times B^y = (A \times B)^{x+y} \quad \textbf{AND} \quad \frac{A^x}{B^y} = (A \times B)^{x-y}$$

EXAMPLE 1

$$(8 \times 10^7) \times (4 \times 10^3)$$

RE-ARRANGE

$$= (8 \times 4) \times (10^7 \times 10^3)$$

$$= 32 \times 10^{7+3}$$

APPLY THE RULE

$$= 32 \times 10^{10}$$

$$= 3.2 \times 10^{11}$$

CONVERT TO STANDARD FORM

REMEMBER, IT'S GOT TO BE BETWEEN 1 AND 10 - 32 IS NOT CORRECT!

EXAMPLE 2

$$(8 \times 10^7) \div (4 \times 10^3)$$

RE-ARRANGE

$$= (8 \div 4) \times (10^7 \div 10^3)$$

$$= 2 \times 10^{7-3}$$

APPLY THE RULE

$$= 2 \times 10^4$$

WE DON'T NEED TO CONVERT, BECAUSE 2 IS ALREADY BETWEEN 1 AND 10

TASK 1: CALCULATION PRACTICE

15-20 MINS

Now try some calculations yourself:

1. $(3 \times 10^4) \times (8 \times 10^2) = ?$
2. $\dfrac{(8.4 \times 10^6)}{(2.1 \times 10^2)} = ?$
3. $(9 \times 10^2) \times \dfrac{(5 \times 10^9)}{(2.5 \times 10^3)} = ?$

Can you prove these harder calculations?

4. $(5 \times 10^6) \times \dfrac{2.4 \times 10^2}{1.2 \times 10^8} = 10$
5. $\dfrac{10^3 \times 10^{-2} \times 10^7}{10^{-5} \times 10^4} = 10^9$

TASK 2: GRAVITY

10 MINS

Can you use the rules above and the values on the previous page to **calculate the standard form of F?**

$$F = \frac{G m_1 m_2}{r^2}$$

Challenge: try working out the order of magnitude first **without** using a calculator!

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ACCURACY & PRECISION

The precision of a value is a lot clearer when we put really big or really small numbers in standard form.
But what exactly do we mean by **precision?**
And how is it different to **accuracy** in the context of physics?

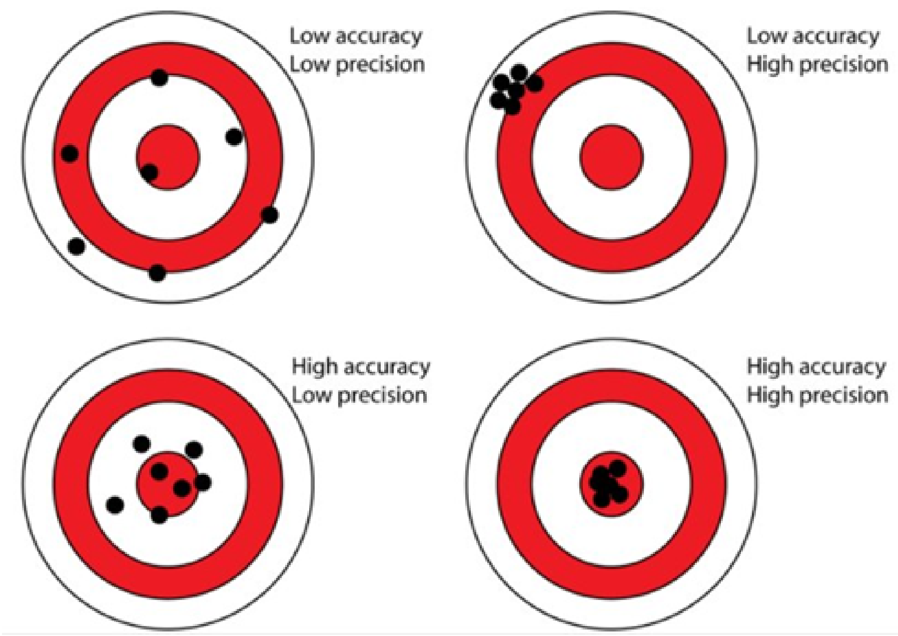
THIS ISN'T ALWAYS SOMETHING THAT WE KNOW!

ACCURACY How **close** a measurement is to the **true value**

PRECISION A measure of the **spread of results,** the exactness of a value

WHAT WE WANT AS PHYSICISTS:

- HIGH ACCURACY
- HIGH PRECISION



TASK 3: ACCURACY VS PRECISION

5 MINS

A person decides to measure **what time sunset is** each day.
What they do:

1. They use a radio-controlled clock
2. They take a reading to the nearest 100 ms as soon as sunlight enters their room in the morning
3. The horizon to the east (direction of sunrise) is obscured by a few trees and buildings

How would you describe these readings in terms of **accuracy** and **precision?**

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TASK 4: RECORDING DATA

5 MINS

What you have learned so far is very important when it comes to **how we record data.** The following table contains many **errors.**

Can you think of **at least 3 ways** this table can be improved?

HINT: some errors relate to what you've learnt this session, and some don't!

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

OPTIONAL EXTRAS

Can you find the value of E in the following equations? Try **not** to use a calculator!

*If you need to use a calculator, try to find the **order of magnitude** of E without one to check that your calculations were correct.*

$$E = mc^2$$

1. Conservation of energy tells us that energy can't be created or destroyed. But it can be **converted** into other forms. Einstein discovered that it is even equivalent to matter!

What is the **energy of an electron** using these values?

we are ignoring kinetic and potential energy

$m_e = 9.11 \times 10^{-31}$ kg

$c = 2.99 \times 10^{8}$ m/s

2. This is the equation for **electric field strength, E.** *Q* is the electric charge, *r* is the distance from the charge, and ε is the permittivity of free space.

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

What is the **electric field strength** 2.4 nm away from an alpha particle using these values?

$Q = 3.20 \times 10^{-16}$ C

$\varepsilon_0 = 8.85 \times 10^{-12}$ F/m

$r = 2.4$ nm