Module 2 Foundations in Physics

Module 2: Foundations of physics

The aim of this module is to introduce important conventions and ideas that permeate the fabric of physics. Understanding of physical quantities, S.I. units, scalars and vectors helps physicists to effectively communicate their ideas within the scientific community (HSW8, 11).

You are here! →

Module 2 – Foundations of physics

2.1	Physical quantities and units
2.2	Making measurements and analysing data
2.3	Nature of quantities

Module 3 – Forces and motion

3.1	Motion
3.2	Forces in action
3.3	Work, energy and power
3.4	Materials
3.5	Newton's laws of motion and momentum

Module 4 – Electrons, waves and photons

4.1	Charge and current
4.2	Energy, power and resistance
4.3	Electrical circuits
4.4	Waves
4.5	Quantum physics

2.1 Physical Quantities & Units

2.1.1 Physical quantities

Learning outcomes

Learners should be able to demonstrate and apply their knowledge and understanding of:

(a) physical quantities have a numerical value and a unit

(b) making estimates of physical quantities listed in this specification.

2.1.2 S.I. units

Learning outcomes

Learners should be able to demonstrate and apply their knowledge and understanding of:

(a) Système Internationale (S.I.) base quantities and their units – mass (kg), length (m), time (s), current (A), temperature (K), amount of substance (mol)

(b) derived units of S.I. base units

(c) units listed in this specification

(d) checking the homogeneity of physical equations using S.I. base units

(e) prefixes and their symbols to indicate decimal submultiples or multiples of units – pico (p), nano (n), micro (μ), milli (m), centi (c), deci (d), kilo (k), mega (M), giga (G), tera (T)

(f) the conventions used for labelling graph axes and table columns.

What is a Quantity?

Physical Quantities

- In everyday life, quantity means amount.
  - A quantity of eggs in a recipe might be 3.

- In physics, a quantity is a measurement of something **and** its unit.

Quantities: What are the units?

- Length
- Area
- Volume
- Time
- Mass
- Angle
- Speed
- Energy
- Electrical Charge
- Resistance

Significant figures v Decimal places

- Significant figures are more important in Physics than decimal places.
  - These are the known figures in a measurement.

- When counting significant figures:
  - Don’t count any zeros to the left of the first figure.
  - Don’t count any zeros to the right of last figure.

How many significant figures do these numbers have?

486	3
486.41	5
0.0087	2
0.00870	3
1000000	1
1000001	7
1.42×10^3	3
2.008×10^8	4

Units

- We often hear of many different units for various quantities:
  - Eg. Length can be measured in metres, feet, miles, etc.

- Scientists from around the world agreed to use a single unit for each quantity.
  - These are called the Système International (or SI) units.

6 Base Units

- All the units you will use in Physics are based on (or derived from) just 6 fundamental (base) units:

Quantity	Unit	Abbreviation
Mass	Kilogram	Kg
Length	Metre	m
Time	Second	s
Temperature	Kelvin	K
Electrical Current	Ampere	A
Amount of substance	Mole	mol

Unit Prefixes

- For very large measurements (149600000000m to the sun) or for very small measurements (0.00000006m cell membrane thickness), a system of prefixes was produced.

Prefix	Name	Abbreviation
10^{-12}	Pico	p
10^{-9}	Nano	n
10^{-6}	Micro	μ
10^{-3}	Milli	m
10^{-2}	Centi	c
10^{3}	Kilo	k
10^{6}	Mega	M
10^{9}	Giga	G
10^{12}	Tera	T

Take Care!!!!

- Many students lose marks converting one unit to another.
- Check your work at each stage in a calculation.

- Areas & volumes can be extra tricky:
  - What is the area of a 4cm x 6cm rectangle in m^2?
    - Change the lengths into metres BEFORE multiplying them: 0.04m x 0.06m = 0.0024m^2

Can you complete the table?

Original value	Value in standard form to 3 s.f.	Value in standard form to 2 s.f.
2710 m	2.71×10^{3} m	2.7×10^{3} m
0.0814 A	8.14×10^{-2} A	8.1×10^{-2} A
307.2 s	3.07×10^{2} s	3.1×10^{2} s
5000 V (± 1 V)	5.00×10^{3} V	5.0×10^{3} V
663×10^{-36} J s	6.63×10^{-34} J s	6.6×10^{34} J s
2185×10^{16} km	2.19×10^{22} m	2.2×10^{22} m
175×10^{-5} pm	1.75×10^{-15} m	1.8×10^{-15} m
6348×10^{-10} m	6.35×10^{2} nm	6.3×10^{-2} nm

How can we estimate some quantities?

Estimated Quantities

- You may be asked to estimate a quantity (eg. The radius of the Earth).
  - You will not be expected to get the correct answer.
  - You will be expected to be within the correct order of magnitude (power of 10).
  - Your answer should be written in the standard SI unit for that quantity.
  - You are expected to show your working.
  - You should use an appropriate number of significant figures.
    - Use 1 fewer SF in the final answer than you did for your working.

So how can we do this?

- Estimate the radius of the Earth.
  - Start with something you do know.
    - Earth's circumference is about 24000 miles. **2 SF**
  - Use this to work out what you need to know.
    - Circ = $2\pi r$
    - r = Circ/2π = 24000/6.3 = 3800 miles **2 SF**
  - Convert to SI units
    - 3800 miles = 3800 x 8/5 km = 6100 km
    - 6100 km = 6100000 m = 6×10^6 m **1 SF**

Actual radius of Earth = 6.4×10^6 m

Estimate these...

- Distance from Bicester to London.
  - 50 miles = 80km = $8x10^4$m
- Mass of an Eddie Stobart lorry with trailer.
  - 40000kg = $4x10^4$kg
- Time taken to drive from Bicester to London.
  - 1 ½ hrs = 90min = 5400s = $5x10^3$s
- Diameter of a cell nucleus.
  - 40nm = 0.00000004 = $4x10^{-8}$m

What are derived quantities?

Base Quantities

- The base quantities are the ones we saw earlier (mass, length, time, etc) with their base units (kg, m, s, etc).

- There are many other quantities though:
  - Volume
  - Velocity
  - Density

These are called derived quantities, they have units which are derived from the base units.

Derived quantities without special names

- What is the unit for velocity?
  - Metres per second, ms^{-1}
- How can we work out the derived unit?
  - Look at the equation which defines the quantity:
    - Velocity = displacement / time
  - Then look at the units:
    - If displacement is divided by time, the units for displacement must be divided by the units for time.
    - The unit for velocity is therefore ms^{-1}

What are the units for these derived quantities?

Derived quantity	Derived unit
Area	m^2
Density	kgm^{-3}
Acceleration	ms^{-2}

Derived quantities with special names

- Some derived quantities are used so often they have been given special names.
- See if you can work out the alternative units or equations for each one...

Derived Quantity	**Unit name**	**Unit symbol**	**Equation**	**Alternative unit**
Force	Newton	N	= mass x acceleration	$Kgms^{-2}$
Pressure	Pascal	Pa	= force / area	Nm^{-2}
Work done	Joule	J	= force x distance	Nm
Power	Watt	W	= energy / time	Js^{-1}
Potential difference	Volt	V	= energy / charge	JC^{-1}
Electrical resistance	Ohm	Ω	= voltage / current	VA^{-1}
Electrical charge	Coulomb	C	= current x time	As

We can use the units to check whether equations are correct

- If an equation is correct, the units on the left hand side MUST be the same as the units on the right.
  - The units must be homogenous
  - Have a go at checking these:
    - $v^2 = 2as$
    - $v = at$
    - $vs = t^2a$
    - $s = vt$

Where:
v = velocity
a = acceleration
t = time
s = displacement

What does OCR look for when recording data?

Tables of data

Independent variables in left hand columns.

Dependent variable in right hand column.

Slash separates quantity from unit.

V/V	I/A	R/Ω
0.15	1.01	0.15
0.32	2.12	0.15
0.38	2.42	0.16

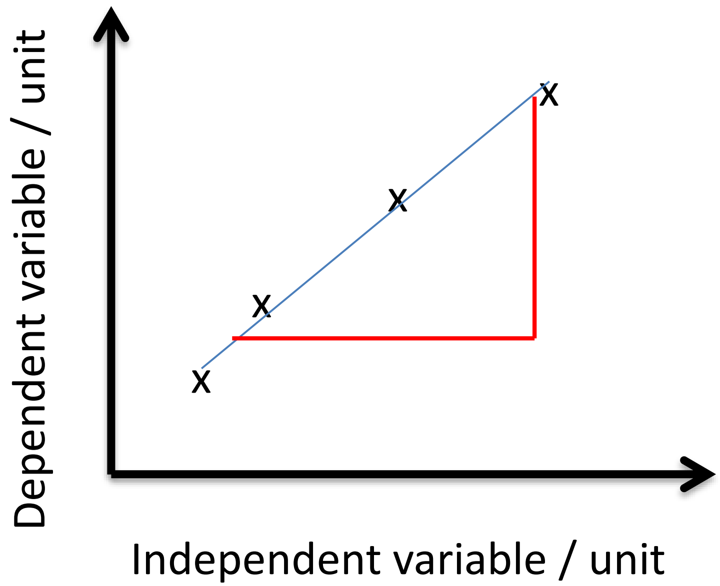
Calculated quantities confined to the lowest sig figs of the data used to calculate it

Data all to the same number of sig figs

Plotting graphs

Choose sensible scales (multiples of 2, 4, 5, 10 NOT multiples of 3, 7, 11, etc)

Use over half of the available graph paper in both directions for your plots.



A gradient can also be calculated from y=mx+c

When calculating a gradient, show a large triangle used.

Plot points using small X rather than ●

Don’t extrapolate a line of best fit

Some graphs in physics will not be straight lines

- Consider plotting a displacement-time graph for an object experiencing constant acceleration...

T / s	S / m
0.0	0.0
1.0	2.0
2.0	8.0

- What shape will it be?

- How could you determine the value of the acceleration? (hint: $s=at^2/2$)
  - Plot displacement against time^2
  - The gradient of this line will be a/2 ($\mathbf{s}=a\mathbf{t^2}/2$)

2.1 Physical Quantities & Units (review)

2.1.1 Physical quantities

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