# Physical Quantities and Units

PHYSICS

## A. PHYSICAL QUANTITIES

- **Physical Quantities** consist of **a numerical magnitude and a unit**

$2\ kg$

Magnitude → 2, Unit → kg

## B. SI UNITS

- **Système Internationale (SI) units** are the international agreed-upon standards for measurement

- All SI Units are based on **7 base units**

| Base Quantity | Base Unit | Symbol |
|---|---|---|
| Mass | Kilogram | Kg |
| Length | Metre | m |
| Time | Second | s |
| Temperature | Kelvin | K |
| Electric current | Ampere | A |
| Amount of substance | Mole | Mol |
| Luminous intensity | Candela | cd |

- For large or small values, the following **prefix** is used to denote the multiplying factor

| Prefix | Symbol | Multiplying Factor |
|---|---|---|
| **Tera** | T | $10^{12}$ |
| **Giga** | G | $10^{9}$ |
| **Mega** | M | $10^{6}$ |
| **Kilo** | k | $10^{3}$ |
| **Deci** | d | $10^{-1}$ |
| **Centi** | c | $10^{-2}$ |
| **Mili** | m | $10^{-3}$ |
| **Micro** | µ | $10^{-6}$ |
| **Nano** | n | $10^{-9}$ |
| **Pico** | p | $10^{-12}$ |

- An equation is **homogenous** if all the terms have the **same base units**

- Derived units consist of **combinations of base units**, either by **multiplying or dividing**

## C. ERRORS AND UNCERTAINTIES

- **Accuracy** refers to the **closeness of a measured value to the true value**

- **Precision** refers to **how close a set of measurements** are **to each other**

- **Uncertainty** is the **total range of values** within which the **measurement is likely to lie**

- **Types of uncertainty**
  For Example: (10 ± 0.5) cm

  Absolute uncertainty : **0.5 cm**
  Percentage uncertainty:

$$\frac{\Delta x}{x} \times 100\%$$

$$\frac{0.5}{10} \times 100\% = 5\%$$

- Combining uncertainties
  1. **For addition/subtraction**
     Add the absolute uncertainties
  2. **For multiplication/division**
     Add the percentage uncertainties
  3. **For powers/radicals**
     Multiply the percentage uncertainties by the power

- Type of Errors
  1. **Systematic Error**
     a. Caused by **instrument error**
     b. Readings are **consistently higher or lower** than true value
     c. **Can't be reduced** by repeated measurements
     d. **Affects the accuracy** of a measurement

     Examples:
     Zero error, wrong calibration, and reaction time of experimenter
  2. **Random Error**
     a. Usually caused by **human error**
     b. Readings are **scattered around** the true value
     c. **Can be reduced** by repeated measurements
     d. **Affects the precision** of a measurement

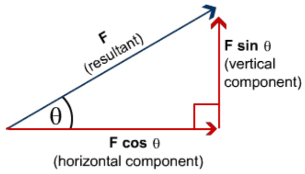
     Examples:
     Reading a scale and parallax error

## D. SCALARS AND VECTORS

- **Scalar quantities** have **a magnitude and a unit**, for example mass, energy, speed, etc

- **Vector quantities** have a **magnitude, unit, and a direction** for example velocity, force, momentum, etc

- **Vectors can be resolved** into **a vertical and horizontal component** as follows




- Vectors can be added by **adding** the respective **perpendicular components**

- **Direction of a vector**

$$\theta = \tan^{-1}\left(\frac{y}{x}\right)$$

## E. EXERCISE

**1. [9702_w09_qp_12_001]**

The drag force F acting on a moving sphere obeys an equation of the form $F = kAv^2$, where A represents the sphere's frontal area and v represents its speed.
What are the base units of the constant k?

**Solution**

The SI unit for force is $kg\ m\ s^{-2}$
We want the right side of the equation to equal to this, so

$$\mathbf{k}Av^2 = kg\ m\ s^{-2}$$
$$\mathbf{k} \times m^2 \times (m\ s^{-1})^2 = kg\ m\ s^{-2}$$
$$\mathbf{k} \times m^2 \times m^2\ s^{-2} = kg\ m\ s^{-2}$$
$$\mathbf{k} = \frac{kg\ m\ s^{-2}}{m^2\ m^2\ s^{-2}}$$
$$\mathbf{k} = kg\ m^{-3}$$

**2. [9702_s19_qp_12_002]**

What is the number of SI base units required to express electric field strength and power?

**Solution**

Recall that power is work per time

$$P = \frac{W}{t}$$
$$P = \frac{Fs}{t}$$
$$P = \frac{ma \times s}{t}$$
$$P_{units} = kg\ m\ s^{-2} \times m \times s^{-1}$$
$$P_{units} = kg\ m^2\ s^{-3}$$

So Power has 3 SI base units

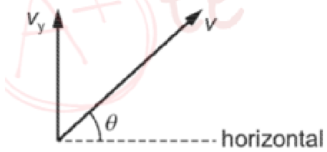
Recall that electric field strength is volt per distance

$$E = \frac{V}{d}$$
$$E = \frac{W}{Qd}$$
$$E = \frac{Fs}{Itd}$$
$$E = \frac{kg\ m\ s^{-2} \times m}{A\ s\ m}$$
$$E = kg\ m\ A^{-1}\ s^{-3}$$

So Electric Field Strength has 4 SI base units

**3. [9702_w21_qp_12_003]**

A tennis ball is hit so that it leaves the racket with velocity v at an angle $\theta$ to the horizontal




The vertical component of the velocity is $v_y$.
What is the magnitude of the horizontal component v?

**Solution**

There are two ways to find it,
the first one is using trigonometry

Since $\cos\theta = \frac{adjacent}{hypotenuse}$, then

$$\cos\theta = \frac{v_x}{v}$$
$$v_x = v\cos\theta$$

The second way is to use the pythagorean theorem

Since $a^2 + b^2 = c^2$, then

$$v_x^2 + v_y^2 = v^2$$
$$v_x^2 = v^2 - v_y^2$$
$$v_x = \sqrt{v^2 - v_y^2}$$

Answer depends on which is available in its multiple choices

**4. [9702_w17_qp_13_001]**

How many cubic nanometres, $nm^3$, are in a cubic micrometre, $\mu m^3$?

**Solution**

A micrometre is $10^{-6}m$
A nanometre is $10^{-9}m$

$$1\ \mu m^3 = (1 \times 10^{-6}m)^3$$
$$1\ \mu m^3 = 1 \times 10^{-18}m^3$$

$$10^{-18}m^3 = n \times 1\ nm^3$$
$$10^{-18}m^3 = n \times (1 \times 10^{-9}m)^3$$
$$10^{-18}m^3 = n \times 10^{-27}m^3$$
$$n = \frac{10^{-18}m^3}{10^{-27}m^3}$$
$$n = 10^9$$

**5.** **[9702_s18_qp_12_001]**
A sheet of gold lead has a thickness of $0.125\mu m$. A gold atom has a radius of 174pm. Approximately how many layers of atoms are there in the sheet?

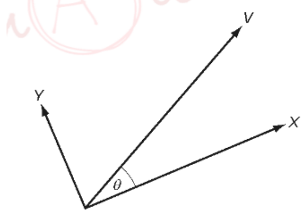
**Solution**
Every atom is going to contribute a diameter worth of length to the thickness of the gold sheet

Change all to SI unit to make it easier

$$layers\ of\ atoms = \frac{thickness}{diameter\ of\ atom}$$
$$layers\ of\ atoms = \frac{0.125 \times 10^{-6}}{2 \times 174 \times 10^{-12}}$$
$$layers\ of\ atoms = 359.19$$

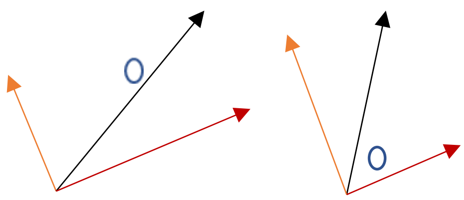
Round to 360 or 400 depending on the multiple choices available

**6.** **[9702_s10_qp_13_002]**
VA vector quantity V is resolved into two perpendicular components X and Y. The angle between V and component X is $\theta$




The angle between component X and the vector V is increased from $0°\ to\ 90°$.
How do the magnitudes of X and Y changes as the angle $\theta$ is increased in this way?

**Solution**



As we can see from the diagram, increasing the angle will decrease the X component and increase the Y component given that vector V is constant

**7.** **[9702_s10_qp_13_002]**
A student measures the time T for one complete oscillation of a pendulum of length l. Her results are shown in the table

| $l$ / m | $T$ / s |
|---|---|
| 0.420 ± 0.001 | 1.3 ± 0.1 |

She uses the formula

$$T = 2\pi\sqrt{\frac{l}{g}}$$

to calculate the acceleration of free fall g. What is the best estimate of the percentage uncertainty in the value og g?

**Solution**
Rearranging the formula for g

$$g = \frac{4\pi^2 l}{T^2}$$

Add the percentage uncertainty ignore constants exponents become multipliers

$$\frac{\Delta g}{g} = \frac{\Delta l}{l} + 2\frac{\Delta T}{T}$$
$$\frac{\Delta g}{g} = \frac{0.001}{0.420} + 2\left(\frac{0.1}{1.3}\right)$$
$$\frac{\Delta g}{g} = 0.156$$
$$percentage$$
$$0.156 \times 100\%$$
$$15.6\%$$

So the percentage uncertainty of g is 15.6% (round up if necessary)