1.1 Use of SI Units & Their Prefixes

PHYSICS

AQA A Level Revision Notes

A Level Physics AQA

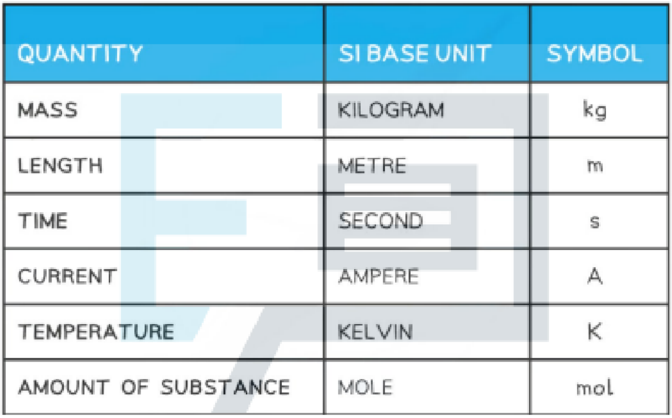
1.1 Use of SI Units & Their Prefixes

CONTENTS

SI Base Quantities

- There is a seemingly endless number of units in Physics
- These can all be reduced to six base units from which every other unit can be derived
- These six units are referred to as the SI Base Units; this is the only system of measurement that is officially used in almost every country around the world

SI Base Quantities Table



QUANTITY	SI BASE UNIT	SYMBOL
MASS	KILOGRAM	kg
LENGTH	METRE	m
TIME	SECOND	s
CURRENT	AMPERE	A
TEMPERATURE	KELVIN	K
AMOUNT OF SUBSTANCE	MOLE	mol

Exam Tip

You will only be required to use the first five SI base units in this course, so make sure you know them!

Derived Units

- Derived units are derived from the seven SI Base units
- The base units of physical quantities such as:
    - Newtons, **N**
    - Joules, **J**
    - Pascals, **Pa,** can be deduced

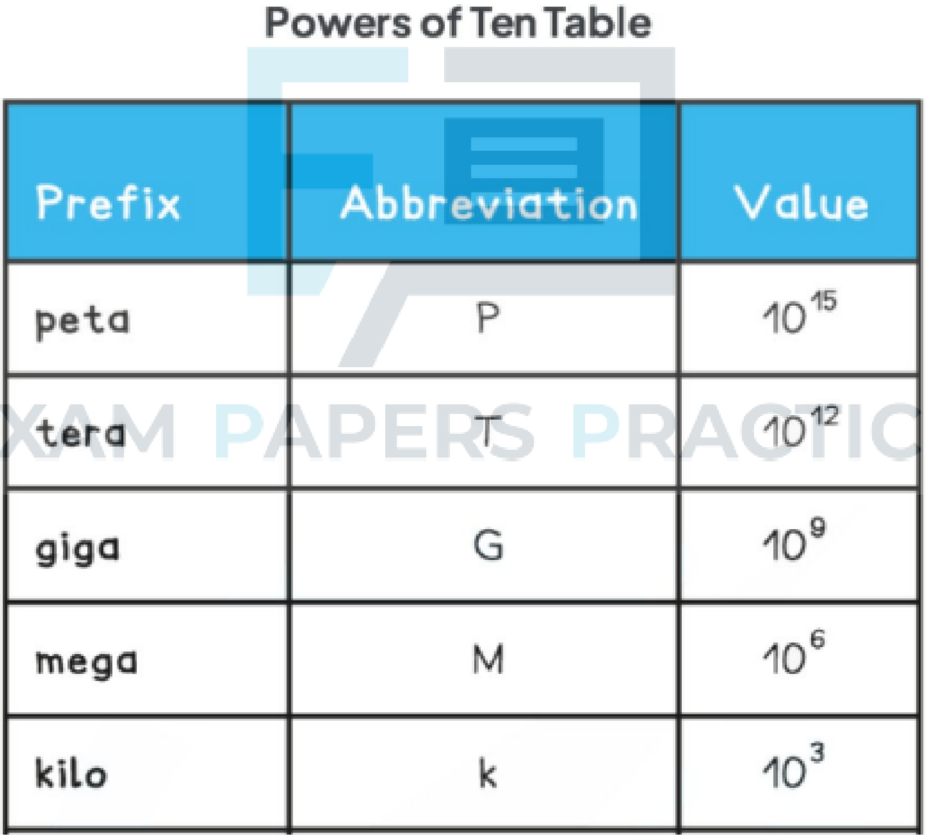
- To deduce the base units, it is necessary to use the definition of the quantity
- The Newton (N), the unit of force, is defined by the equation:
    - Force = mass × acceleration
    - $N = kg \times m\,s^{-2} = kg\,m\,s^{-2}$
    - Therefore, the Newton (N) in SI base units is $\mathbf{kg\,m\,s^{-2}}$

- The Joule (J), the unit of energy, is defined by the equation:
    - Energy = ½ × mass × velocity^2
    - $J = kg \times (m\,s^{-1})^2 = kg\,m^2\,s^{-2}$
    - Therefore, the Joule (J) in SI base units is $\mathbf{kg\,m^2\,s^{-2}}$

- The Pascal (Pa), the unit of pressure, is defined by the equation:
    - Pressure = force ÷ area
    - $Pa = N \div m^2 = (kg\,m\,s^{-2}) \div m^2 = kg\,m^{-1}\,s^{-2}$
    - Therefore, the Pascal (Pa) in SI base units is $\mathbf{kg\,m^{-1}\,s^{-2}}$

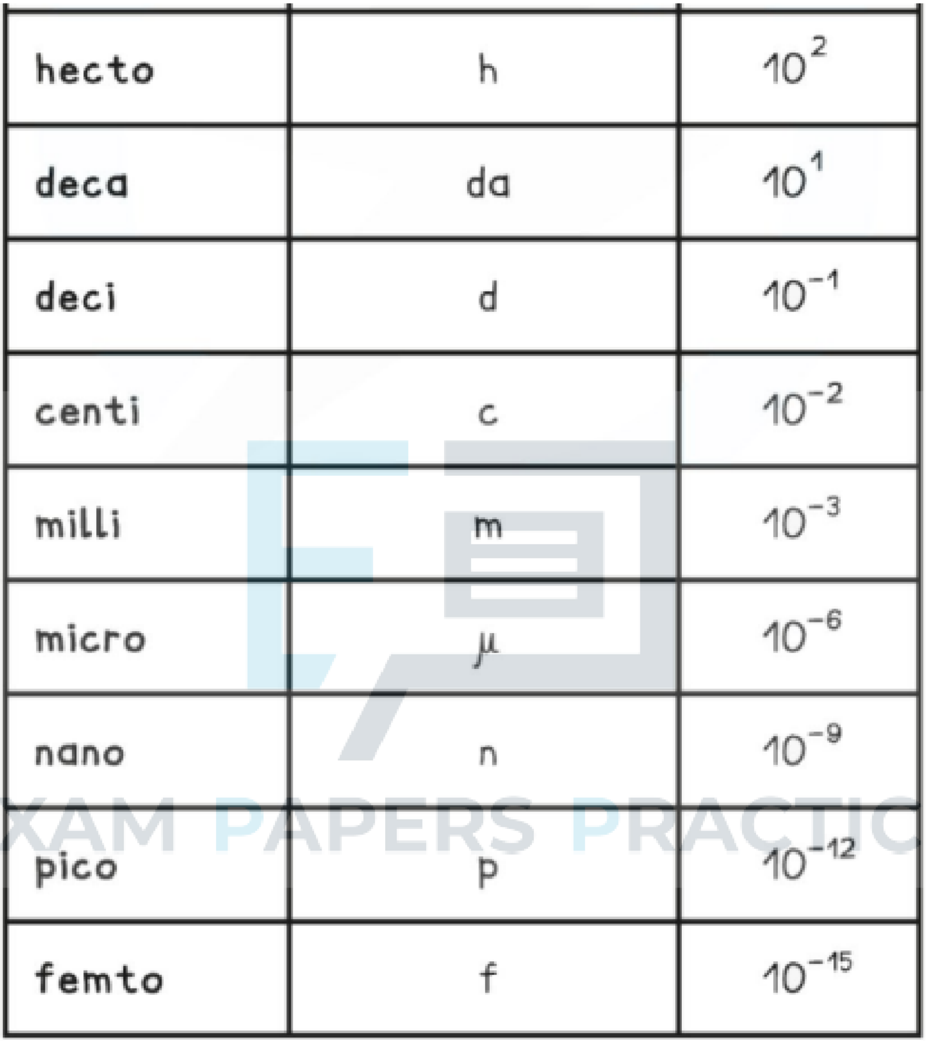
Powers of Ten

- Physical quantities can span a huge range of values
- For example, the diameter of an atom is about 10^{-10} m (0.0000000001 m), whereas the width of a galaxy may be about 10^{21} m (1,000,000,000,000,000,000,000 m)
  - This is a difference of 31 powers of ten
- Powers of ten are numbers that can be achieved by multiplying 10 times itself
- It is useful to know the prefixes for certain powers of ten



Powers of Ten Table

Prefix	Abbreviation	Value
peta	P	10^{15}
tera	T	10^{12}
giga	G	10^{9}
mega	M	10^{6}
kilo	k	10^{3}



hecto	h	10^{2}
deca	da	10^{1}
deci	d	10^{-1}
centi	c	10^{-2}
milli	m	10^{-3}
micro	µ	10^{-6}
nano	n	10^{-9}
pico	p	10^{-12}
femto	f	10^{-15}

Examples

- 5 kN = 5 kilonewtons = 5×10^{3} N (5000 N)

- 7 nC = 7 nanocoulombs = 7 × 10^{-9} C (0.000000007 C)

Exam Tip

You will often see very large or very small numbers categorised by powers of ten, so it is very important you become familiar with these as getting these prefixes wrong is a very common exam mistake!

Common Unit Conversions

J & eV

- A common unit conversion in physics is between Joules (J) and electronvolts (eV)
- The electronvolt is derived from the equation work done (or energy transferred) $W = qV$
    - 1 eV = 1.6 × 10^{-19} C × 1 V = 1.6 × 10^{-19} J
- To convert from J → eV, divide by 1.6 × 10^{-19}
- To convert from eV → J, multiply by 1.6 × 10^{-19}

J & kW h

- Another common unit conversion in physics is between Joules (J) and kilowatt-hours (kW h)
- To convert between J and kW h, expand the derived units and re-collect terms as follows:
    - 1 kW h = 3600 kW s (since 1 hour = 3600 s)
    - 3600 kW s = 3 600 000 W s (since 1 kW = 1000 W)
    - 3 600 000 W s = 3 600 000 J = 3.6 MJ (since power = energy / time or 1 W = 1 J s^{-1})
- To convert from J → kW h, divide by 3.6 × 10^6
- To convert from kW h → J, multiply by 3.6 × 10^6

Worked Example

The ionisation energy of hydrogen is 2.176 × 10^{-18} J. Calculate this energy in eV.

- To convert from J → eV, divide by 1.6 × 10^{-19} J

$$\text{Energy in eV} = \frac{2.176 \times 10^{-18}}{1.6 \times 10^{-19}} = 13.6 \text{ eV}$$

1.1.3 Estimating Physical Quantities

Orders of Magnitude

- When a number is expressed in an **order of 10**, this is an **order of magnitude**.
    - Example: If a number is described as 3×10^8 then that number is actually 3 × 100 000 000
    - The **order of magnitude** of 3×10^8 is just $\mathbf{10^8}$

- Orders of magnitude follows rules for rounding
    - The **order of magnitude** of 6×10^8 is $\mathbf{10^9}$ as the magnitude is **rounded up**

- A quantity is an **order of magnitude larger** than another quantity if it is about **ten times larger**
- Similarly, **two orders of magnitude** would be **100 times larger,** or 10^2
    - In physics, orders of magnitude can be very large or very small

- When estimating values, it's best to give the **estimate** of an order of magnitude to **the nearest power of 10**
    - For example, the diameter of the Milky Way is approximately 1 000 000 000 000 000 000 000 m

- The order of magnitude is 10^{21}
- Orders of magnitude make it easier to compare the relative sizes of objects
    - For example, a quantity with an order of magnitude of 10^6 is 10 000 times larger than a quantity with a magnitude of 10^2

Order of Magnitudes Table

Object of interest	Approximate length (m)	Order of magnitude (m)
Distance to the edge of the observable universe	4.40×10^{26}	10^{26}
Distance from Earth to Neptune	4.5×10^{12}	10^{12}
Distance from London to Cape Town	9.7×10^{6}	10^{7}
The length of a human	1.7	10^{0}
The length of an ant	9×10^{-4}	10^{-3}
The length of a bacteria	2×10^{-6}	10^{-6}

? Worked Example

Estimate the order of magnitude for the following quantities:

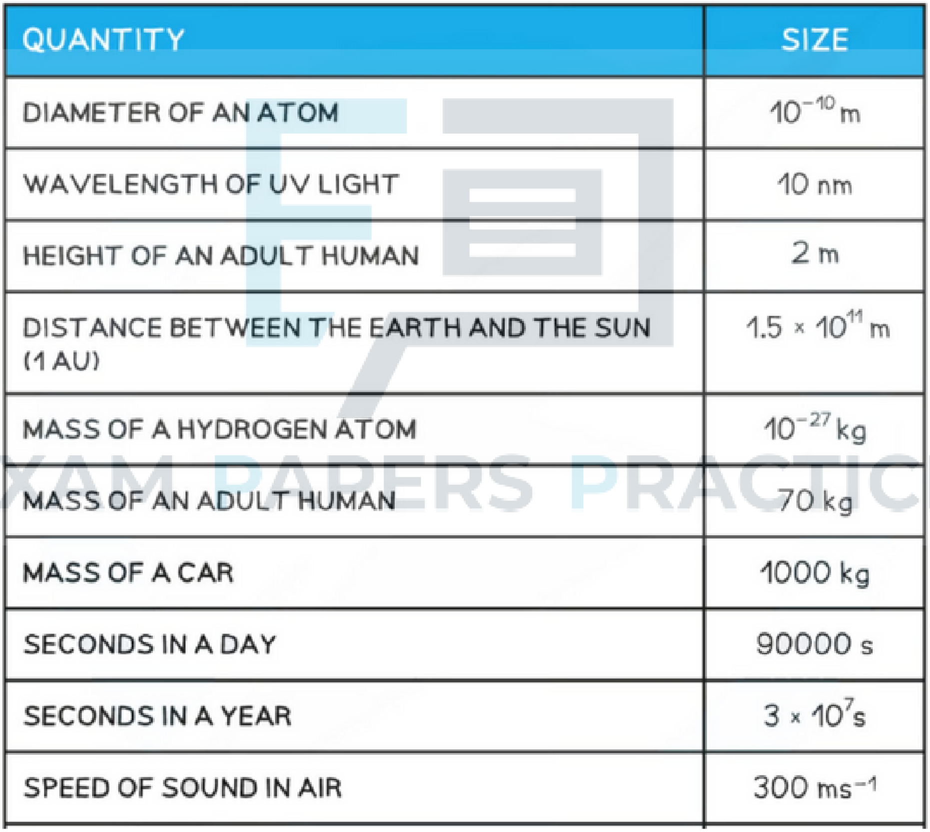
1. The temperature of the surface of the Sun in Kelvin
2. The power of a standard lightbulb
3. The volume of the room you are in now

1. The temperature of the surface of the Sun in Kelvin
    - The temperature of the surface of the Sun is about 6000 K
    - This is an order of magnitude of ~ 10^4 K
2. The power of a standard lightbulb
    - The power of a standard lightbulb is about 60 W
    - This is an order of magnitude of ~ 10^2 W
3. The volume of the room you are in now
    - This depends on the room you are in
    - The shape should roughly be cubic or (rectangular) cuboid
    - Volume = length × width × height
    - For a cubic room with length 3 m, volume = $3^3 = 27$ m^3
    - This is an order of magnitude of ~ 10 m^3

Estimating Physical Quantities

- There are important physical quantities to learn in physics
- It is useful to know these physical quantities, they are particularly useful when making estimates
- A few examples of useful quantities to memorise are given in the table below (this is by no means an exhaustive list)

Estimating Physical Quantities Table

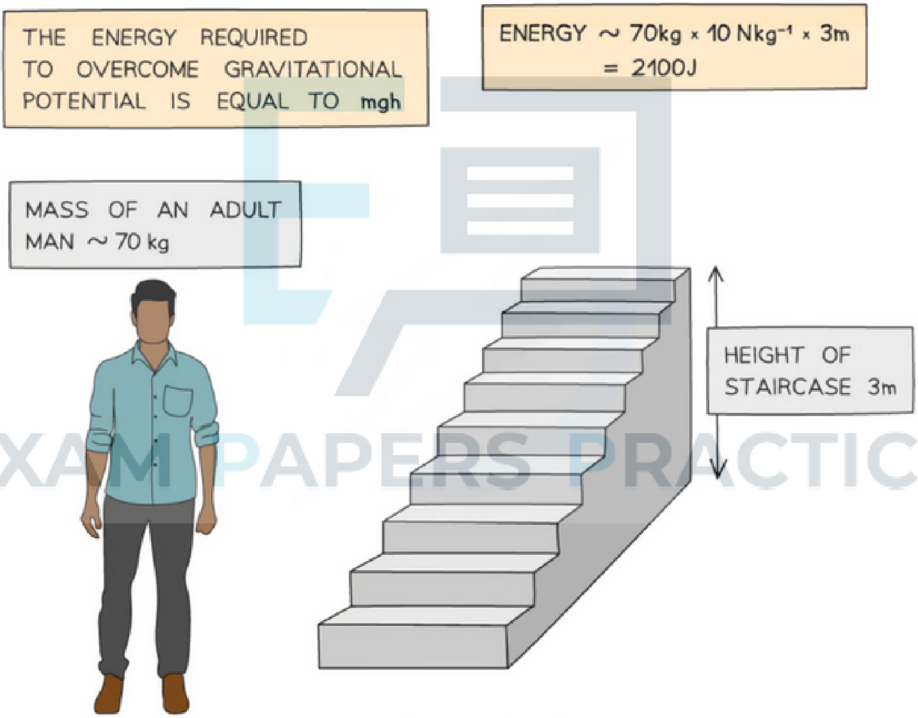


QUANTITY	SIZE
DIAMETER OF AN ATOM	10^{-10} m
WAVELENGTH OF UV LIGHT	10 nm
HEIGHT OF AN ADULT HUMAN	2 m
DISTANCE BETWEEN THE EARTH AND THE SUN (1 AU)	1.5×10^{11} m
MASS OF A HYDROGEN ATOM	10^{-27} kg
MASS OF AN ADULT HUMAN	70 kg
MASS OF A CAR	1000 kg
SECONDS IN A DAY	90000 s
SECONDS IN A YEAR	3×10^{7} s
SPEED OF SOUND IN AIR	300 ms^{-1}

POWER OF A LIGHTBULB	60W
ATMOSPHERIC PRESSURE	1×10^5 Pa

Worked Example

Estimate the energy required for an adult man to walk up a flight of stairs.



THE ENERGY REQUIRED TO OVERCOME GRAVITATIONAL POTENTIAL IS EQUAL TO mgh

ENERGY $\sim 70\text{kg} \times 10\ \text{Nkg}^{-1} \times 3\text{m}$

$= 2100\text{J}$

MASS OF AN ADULT MAN ~ 70 kg

HEIGHT OF STAIRCASE 3m