Order of Magnitude

The order of magnitude of a number is the number expressed to the nearest ~~whole number~~ integer power of 10.

Pop of Earth: 6.9 billion 6.9×10^9

between 10^9 and 10^{10}

order of magnitude is 10^{10}

Gravitational field strength $9.8\ N\ kg^{-1}$

b/w 10^0 and 10^1

order of magnitude is 10^1 or 10

Mass of an electron: 9.1×10^{-31} kg

b/w 10^{-31} and 10^{-30}

order of magnitude is 10^{-30}

Try these:

1. Atmospheric Pressure at sea level 1.01×10^5 Pa — 10^5
2. Average height of a adult mal 1.784 m — 10^0 m
3. Box of apples has a mass of 16kg — 10^1
4. Cheese 0.075kg — 10^{-1} kg

Rounding with orders of magnitude:

cut off 3.16

Try these:

4.13×10^3	~~10^3~~ 10^4 ✓	
3.09×10^{-6}	10^{-6} ~~10^{-5}~~	
4245	10^3 10^4	$3.3 > 3.16$
0.00033	10^{-4} 10^{-3}	3.3×10^{-4}

Example:

Which of the following is the same as 3.8×10^{-3} to the nearest order of magnitude? 10^{-3} and 10^{-2}

~~a)~~ 3.0×10^{-3}

~~b)~~ 4.0×10^{-2}

c) 10^{-2} $3.8 > 3.16$

d) 10^{-3} round up the order of magnitude.

Very Large numbers / Very small numbers

We are limited by what we can visualize or we have experienced.

objects in this room ~ 1 m

strand of hair ~ 0.1mm or 10^{-4} m

distance to moon ~ 10^{9} m

Can you visualize the speed of light?

$$c = 3.0 \times 10^{8} m s^{-1}$$

- light would travel back + forth across this room a million times every second (about).
- light takes 8 minutes to reach the Earth from the Sun.
- LHC (Large Hadron Collider)
  - 27 km long
  - protons travel at <u>almost</u> the speed of light.
  - travel around the collider 10,000 times a second.
- it takes light 4 years to get to the Earth from our nearest star and 100,000 years to cross Milky way.

You MUST KNOW these:

Distances:

Diameter of a proton	10^{-15} m
Extent of the visible universe	10^{25} m

Masses:

Mass of the electron	10^{-30} kg
Mass of the universe	10^{50} kg

Times:

Time for light to cross a nucleus	10^{-23} s
Age of universe	10^{18} s

Ratios are expressed as a difference in orders of magnitude:

Compare

$$\frac{\text{diameter of H atom}}{\text{diameter of H nucleus}} = \frac{10^{-10}}{10^{-15}} = 10^{5}$$

↑ the diameter of the H atom is 10^5 orders of magnitude larger than the diameter of the nucleus

Example:

The diameter of a proton is about 10^{-15}m and the diameter of a hydrogen atom is about 10^{-10}m.

How many orders of magnitude is the volume of a hydrogen atom greater than the volume of its nucleus? (just a proton for hydrogen)

$V = \frac{4}{3}\pi r^3$

$$\frac{\text{volume of H atom}}{\text{volume of nucleus}} = \frac{\frac{4}{3}\pi\left(\frac{d_{atom}}{2}\right)^3}{\frac{4}{3}\pi\left(\frac{d_{nuc}}{2}\right)^2}$$

$$= \frac{\frac{d_{atom}^3}{2^3}}{\frac{d_{nuc}^3}{2^3}}$$

$$= \frac{d_{atom}^3}{d_{nuc}^3}$$

$$= \frac{(10^{-10})^3}{(10^{-15})^3}$$

$$= \left(\frac{10^{-10}}{10^{-15}}\right)^3$$

$$= (10^5)^3$$

$$= 10^{15}$$

The volume of the hydrogen atom is 10^{15} times bigger than its nucleus (a 15 orders of magnitude bigger)

Example

How many orders of magnitude is the length of a metre stick longer than the width of a pencil?

$$\frac{1m}{0.01m} = 100 = 10^2$$

2 orders of magnitude longer

$$\frac{10^0}{10^{-2}} = 10^2$$