Physics for Engineering I
PHYS 1210

Ch 1: Physics and Measurements

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Lecture Content

- Units
- Density and atomic mass
- Dimensional analysis
- Conversion of units
- Estimates and order of magnitude
- Significant figures

Dimensions and Units

The laws of physics are expressed in mathematical form among physical quantities (F = m a)

A dimension is a property that can be counted, measured, or calculated.

Basic quantities

- Length, mass, time

Derived quantities

- Velocity, acceleration, force, pressure etc…

Unit Systems

SI System

- Length: metre (m), mass: kilogram (kg), time: second (s).

British System (US customary system)

- Length: foot (ft), mass: pound “mass” (lb_m), time: second (s).

Is there any other system of units?

If yes, write a summary describing these systems due by next week

Length, Mass, and Time

- Metre is the unit of length. Defined as the distance travelled by light in vacuum in a time period 1/299792458 s.
- Kilogram is the unit of mass. Defined as the mass of a specific platinum–iridium alloy cylinder.
- The second (s) is now defined as 9192631770 times the period of vibration of radiation from the Cesium atom.
- Atomic clock

Some typical measured values

Approximate Values of Some Measured Lengths

	Length (m)
Distance from the Earth to the most remote known quasar	1.4×10^{26}
Distance from the Earth to the most remote normal galaxies	9×10^{25}
Distance from the Earth to the nearest large galaxy (M 31, the Andromeda galaxy)	2×10^{22}
Distance from the Sun to the nearest star (Proxima Centauri)	4×10^{16}
One lightyear	9.46×10^{15}
Mean orbit radius of the Earth about the Sun	1.50×10^{11}
Mean distance from the Earth to the Moon	3.84×10^{8}
Distance from the equator to the North Pole	1.00×10^{7}
Mean radius of the Earth	6.37×10^{6}
Typical altitude (above the surface) of a satellite orbiting the Earth	2×10^{5}
Length of a football field	9.1×10^{1}
Length of a housefly	5×10^{-3}
Size of smallest dust particles	$\sim 10^{-4}$
Size of cells of most living organisms	$\sim 10^{-5}$
Diameter of a hydrogen atom	$\sim 10^{-10}$
Diameter of an atomic nucleus	$\sim 10^{-14}$
Diameter of a proton	$\sim 10^{-15}$

Approximate Values of Some Time Intervals

	Time Interval (s)
Age of the Universe	5×10^{17}
Age of the Earth	1.3×10^{17}
Average age of a college student	6.3×10^{8}
One year	3.2×10^{7}
One day (time interval for one revolution of the Earth about its axis)	8.6×10^{4}
One class period	3.0×10^{3}
Time interval between normal heartbeats	8×10^{-1}
Period of audible sound waves	$\sim 10^{-3}$
Period of typical radio waves	$\sim 10^{-6}$
Period of vibration of an atom in a solid	$\sim 10^{-13}$
Period of visible light waves	$\sim 10^{-15}$
Duration of a nuclear collision	$\sim 10^{-22}$
Time interval for light to cross a proton	$\sim 10^{-24}$

Masses of Various Objects (Approximate Values)

	Mass (kg)
Observable Universe	$\sim 10^{52}$
Milky Way galaxy	$\sim 10^{42}$
Sun	1.99×10^{30}
Earth	5.98×10^{24}
Moon	7.36×10^{22}
Shark	$\sim 10^{3}$
Human	$\sim 10^{2}$
Frog	$\sim 10^{-1}$
Mosquito	$\sim 10^{-5}$
Bacterium	$\sim 1 \times 10^{-15}$
Hydrogen atom	1.67×10^{-27}
Electron	9.11×10^{-31}

Generating **intuition** about typical values of quantities is important because when solving problems you must think about your end result and determine if it seems reasonable. If you are calculating the mass of a car and arrive at a value of 10 kg, this is *unreasonable—there is an* error somewhere.

Prefixes for power of ten

Prefixes for Powers of Ten

Power	Prefix	Abbreviation
10^{-24}	yocto	y
10^{-21}	zepto	z
10^{-18}	atto	a
10^{-15}	femto	f
10^{-12}	pico	p
10^{-9}	nano	n
10^{-6}	micro	μ
10^{-3}	milli	m
10^{-2}	centi	c
10^{-1}	deci	d
10^{3}	kilo	k
10^{6}	mega	M
10^{9}	giga	G
10^{12}	tera	T
10^{15}	peta	P
10^{18}	exa	E
10^{21}	zetta	Z
10^{24}	yotta	Y

Most frequently used prefixes and should be memorised

Conversion of Units (between the same unit system)

- A measured quantity can be expressed in terms of any units provided the appropriate dimension is used. Velocity can be expressed as m/s, km/hr, mm/day, in/year, ft/s. (length / time).
- Use conversion factor to convert from one unit to another. Ex: convert 36 mg to g?
- 36 mg = 36×10^{-3} g.

Conversion Factors

- Conversion factor should be memorised.

Length

1 in. = 2.54 cm (exact)
1 m = 39.37 in. = 3.281 ft
1 ft = 0.304 8 m
12 in. = 1 ft
3 ft = 1 yd
1 yd = 0.914 4 m
1 km = 0.621 mi
1 mi = 1.609 km
1 mi = 5 280 ft
1 μm = 10^{-6} m = 10^3 nm

Mass

1 000 kg = 1 t (metric ton)
1 slug = 14.59 kg
1 u = 1.66×10^{-27} kg

1 lb_m = 0.454 kg

1 yr = 365 days = 3.16×10^7 s
1 day = 24 h = 1.44×10^3 min = 8.64×10^4 s

- These factors to start with, some will be introduced in the lectures.

Conversion of Units (between systems of unit)

- Use conversion factor to convert from one system of unit to another. Ex: convert 23 $Ib_m \cdot ft/min^2$ to its equivalent in $kg.cm/s^2$?

$$\frac{23\ Ib_m \cdot ft}{min^2}\left(\frac{0.454\ kg}{1\ Ib_m}\right)\left(\frac{100\ cm}{3.28\ ft}\right)\left(\frac{1\ min^2}{60^2\ s^2}\right) = 0.088\ \frac{kg \cdot cm}{s^2}$$

Density and Atomic Mass

- The density is defined as the mass per unit volume.

$$\rho \equiv \frac{m}{V}$$

- Density of water 1000 kg/m^3 , and for aluminium 2700 kg/m^3

Densities of Various Substances

Substance	Density ρ (10^3 kg/m^3)
Platinum	21.45
Gold	19.3
Uranium	18.7
Lead	11.3
Copper	8.92
Iron	7.86
Aluminum	2.70
Magnesium	1.75
Water	1.00
Air at atmospheric pressure	0.0012

Atomic Mass

- The atomic mass of an element is defined as the mass of a single atom of the element. It is measured by atomic mass units (u = 1.66 x 10^{-27} kg).

A solid cube of aluminum (density 2.70 g/cm^3) has a volume of 0.200 cm^3. It is known that 27.0 g of aluminum contains 6.02×10^{23} atoms. How many aluminum atoms are contained in the cube?

$$m = \rho V = (2.70\ \text{g/cm}^3)(0.200\ \text{cm}^3) = 0.540\ \text{g}$$

$$\begin{aligned} m_{\text{sample}} &= kN_{\text{sample}} \\ m_{27.0\ \text{g}} &= kN_{27.0\ \text{g}} \end{aligned} \quad \rightarrow \quad \frac{m_{\text{sample}}}{m_{27.0\ \text{g}}} = \frac{N_{\text{sample}}}{N_{27.0\ \text{g}}}$$

$$\frac{0.540\ \text{g}}{27.0\ \text{g}} = \frac{N_{\text{sample}}}{6.02 \times 10^{23}\ \text{atoms}}$$

$$N_{\text{sample}} = \frac{(0.540\ \text{g})(6.02 \times 10^{23}\ \text{atoms})}{27.0\ \text{g}}$$

$$= 1.20 \times 10^{22}\ \text{atoms}$$

Important to understand solving problems by the ratio technique

Estimates and order of magnitudes calculations

$$0.008\,6 \sim 10^{-2}$$

$$720 \sim 10^{3}$$

$$0.002\,1 \sim 10^{-3}$$

Number of Significant Figures

- You have a ruler and want to measure a rectangular piece of wood. The accuracy of the ruler used is ± 0.1 cm.
- The measured length = 5.5 cm and
- Measured width is 6.4 cm.
- The actual length should be written taken into account the accuracy of the apparatus used (ruler) = 5.5±0.1 cm i.e. the length can be 5.4 to 5.6 cm.
- The width is also 6.4 ± 0.1 cm , i.e. 6.3 to 6.5 cm.
- In this case measured values have two significant figures.

Number of Significant Figures

- What if it is required to find the area of the piece?
- Easy: 5.5 x 6.4 = 35.2 cm^2
- The answer has 3 significant figures????

When multiplying several quantities, the number of significant figures in the final answer is the same as the number of significant figures in the quantity having the lowest number of significant figures. The same rule applies to division.

- The answer should have only two significant figures:

i.e. 35 cm^2

- But the area can be $(5.4\ \text{cm})(6.3\ \text{cm}) = 34\ \text{cm}^2$ $(5.6\ \text{cm})(6.5\ \text{cm}) = 36\ \text{cm}^2$

Number of Significant Figures

- Zero may or not be significant figure.
- When it used to place or position the decimal point it is not counted as a significant figure like 0.0075, 0.03 (two and one significant figures)
- What about the mass of an object = 1500 g. what is the significant figures used here?
- This value is ambiguous because we do not know whether the last two zeros are being used to locate the decimal point or whether they represent significant figures in the measurement.
- Express in scientific form as 1.5×10^3 g, 1.50×10^3 g, 1.500×10^3 g for 2, 3 and 4 significant figures respectively