

Classical Mechanics

- Motion of objects
 - Large objects (much larger than an atom)
 - Slow objects (much smaller than the speed of light)
- Key concepts
 - displacement, velocity and acceleration
 - force
 - energy
 - momentum

Physics and Measurement

- Basic quantities of mechanics
- SI units
- Modeling and quantifying matter
- Problem solving
 - Dimensional analysis
 - Units and conversion
 - Estimates and order of magnitude calculations
 - Significant figures

Basic Quantities of Mechanics

■ Length

- **SI Unit: meters (m)**
- Standard is related to the speed of light

■ Mass

- **SI Unit: kilograms (kg)**
- Standard is a specific Pt-Ru cylinder in France

■ Time

- **SI Unit: seconds (s)**
- Standard is a vibration of a Ce atom.

Range of Values

- Length (m)
 - The farthest quasar = 1.4×10^{26}
 - The moon = 1.5×10^{11}
 - Football field = 9.1×10^1
 - Typical cell $\sim 10^{-5}$
 - Atom $\sim 10^{-10}$
- Mass (kg)
 - Universe $\sim 10^{52}$
 - Earth = 5.98×10^{24}
 - Human $\sim 10^2$
 - Bacterium $\sim 10^{-15}$
 - Hydrogen atom = 1.67×10^{-27}
- Time (s)
 - Age of universe = 5×10^{17}
 - Age of earth = 1.3×10^{17}
 - You $\sim 6.3 \times 10^8$
 - One heartbeat = 8×10^{-1}
 - Nuclear collision $\sim 10^{-22}$

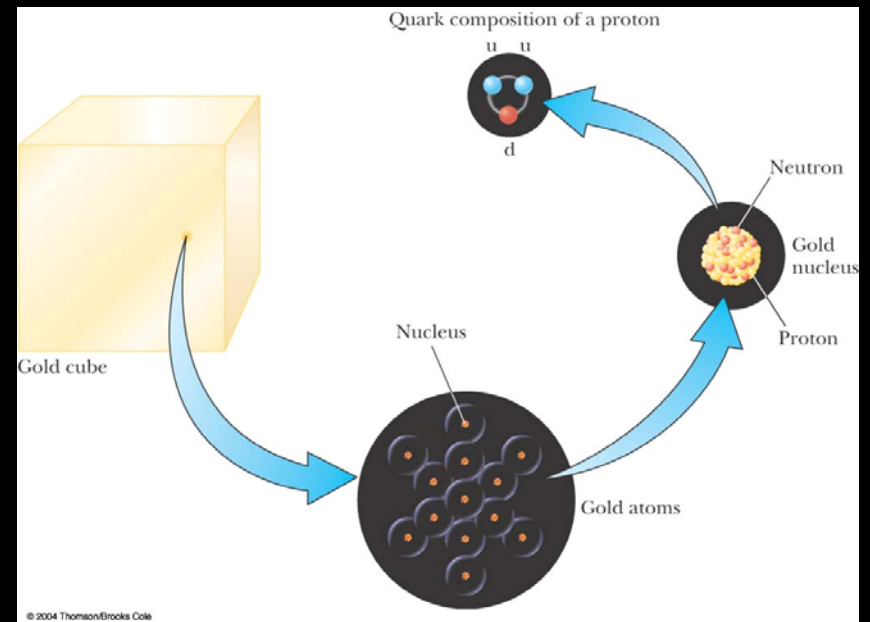
Prefixes for Powers of Ten

Table 1.4

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

Structure of Matter

- Macroscopic objects
- Molecules
- Atoms
- Electrons, protons, neutrons
- Quarks
- ????



Measuring the Amount of Matter

- **Atomic number** = # of protons
 - Specific to an element
- **Mass number** = # protons + # of neutrons
 - Varies from isotope to isotope (– ^{14}C)
- **Atomic Mass** = the mass of a single atom of the element in atomic mass units
 - An average quantity
 - 1 atomic mass unit (u) = 1.66×10^{-27} kg
 - Aluminum = 27 u
 - Lead = 207 u
- **Mole** = the amount of substance that contains as many particles (atoms, molecules, other particles) as there are atoms in 12 g of the ^{12}C isotope.
 - **One mole contains 6.022×10^{23} particles** (Avogadro's number).
 - In general, the mass in 1 mole of any element is the element's atomic mass expressed in grams.

Mass Density

- Mass per unit volume:

$$\rho \equiv \frac{m}{V} \quad (\text{kg/m}^3)$$

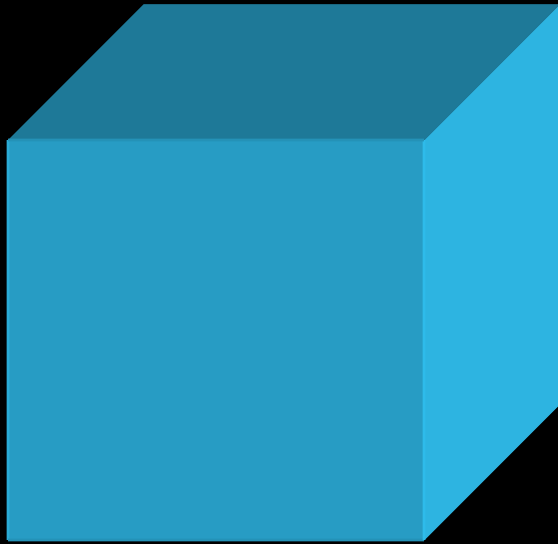
- A derived quantity.

Densities of various substances	
Substance	ρ (10^3 kg/m^3)
Lead	11.3
Aluminum	2.7
Water	1
Air	0.0012

$$\frac{\rho_{Al}}{\rho_{Pb}} = \frac{2.7 \text{ g/cm}^3}{11.3 \text{ g/cm}^3} \neq \frac{amu_{Al}}{amu_{Pb}} = \frac{27u}{207u}$$

Density is not only a measure of the amount of matter but also a measure of how tightly it is packed.

Example - An Iron Block



$$L = 10 \mu\text{m}$$

A small cube of iron is observed under a microscope.

- Find the mass of the block
- Find the number of iron atoms in the block

$$\rho = 7.86 \text{ g/cm}^3$$

$$\text{Molar mass} = 55.9 \text{ g/mole}$$

$$m = 7.86 \times 10^{-12} \text{ kg}$$

$$\# \text{ of atoms} = 8.47 \times 10^{13}$$

Dimensional Analysis

- A “dimension” in physics is the physical nature of a quantity (L, M, T).
 - speed $[v] = L / T$
 - area $[A] = L^2$
- It can be treated as an algebraic quantity.
- Always do a dimensional analysis of a problem.

Newton's law of universal gravitation is represented by the following equation:

$$F = G \frac{Mm}{r^2}$$

$$[G] = \frac{m^3}{kg \cdot s^2}$$

Here F is the gravitational force, M and m are masses, and r is a length.

Force has the SI units $kg \cdot m/s^2$.

What are the SI units of the proportionality constant G ?

Units and Conversion

- It is very important to use the right units for the right physical quantity and keep them consistent throughout a problem.
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Convert the 65 mph highway speed limit to SI units.

$$65\text{mph} = 65 \left(\frac{\text{mi}}{\text{h}} \right) \left(\frac{1609\text{m}}{1\text{mi}} \right) \left(\frac{1\text{h}}{60\text{min}} \right) \left(\frac{1\text{min}}{60\text{s}} \right) = 29.05 \frac{\text{m}}{\text{s}}$$

Estimation and Order of Magnitude

- Assign “common sense / typical” numbers to unknown quantities.
 - Calculate the required quantity to an order of magnitude
 - Do a reality check (does the result make sense?)
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How much gas is used annually by all the automobiles in the U.S.?

- Estimate amount of cars
- Estimate miles driven per car
- Estimate mpg

Significant Figures

- The number of reliably known digits in a measurement.
- When adding and subtracting, use the smallest number of decimal places in any of the terms.
- When multiplying or dividing, use the lowest number of significant figures in any of the terms.

Review

- Length, mass and time are the basic quantities of mechanics
- We use SI units (m, kg, s)
- The structure of matter goes from molecules to atoms to nuclear particles to sub-nuclear particles.
- The amount of matter can be density or moles.
- When solving problems use dimensional analysis, estimation and order of magnitude reasoning to get an idea and to check you answers.
- Keep your units and significant figures straight.