مدونة المناهج السعودية

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الموقع التعليمي لجميع المراحل الدراسية

في المملكة العربية السعودية

General Physics

Code: 4031101-4

Chapter 1

Measurement

Physics Department

College of Science

Units of Chapter 1: Measurements

1. The Physical Quantities,
2. Standards and Units
3. Systems of units
4. The international System of units
5. British system of units
6. Gauss system of units
7. Dimensional Analysis
8. Applications

Learning goals of this chapter

- **On completing this chapter, the student will be able to :**
- Differentiate between the fundamental quantities and the derivative quantities .
- Express the physical quantities using the international system of units.
- Differentiate between the international system of units and the British system of unit.
- Define the standard of time
- Define the standard of length
- Define the standard of mass
- Convert units of the physical quantities from system to another .
- Determine the dimensions of the physical quantity.
- Check the physical formula using dimensional analysis .

The Physical Quantities

There are two types of Physical Quantities

1 Basic Physical Quantity

- **Mass** denoted as **M**
- **Length** denoted as **L**
- **Time** denoted as **T**

2 Derived Physical Quantity

- It is any quantity that can be expressed by the basic quantity, such as area, volume, density, force, velocity, etc.

The Standards and Units

- To describe the physical quantities we need to choose a unit that does not differ from a corresponding quantity physically but has a quite definite dimension.

- Every physical quantity (Y) can be defined as the product of a (unit) multiplied by a number (x):
  - Y = X (unit)
  - For example: **Mass = 5 kg**
  - **Mass** is the physical quantity,
  - **5** is the number.
  - **kg** is the unit used.

Systems of units

There are three common systems of units

1. International system of units
2. British system of units
3. Gaussian (cgs) system of units

The international System of units (SI)

Physical Quantity	Unit	Symbol
Length	Meter	m
Mass	Kilogram	kg
Time	Second	s
Electric current	Ampere	A
Temperature	Kelvin	K
Amount of substance	Mole	mol
Luminous intensity	Candela	cd

British system of units

Physical Quantity	Unit	Symbol
Length	Feet	ft
Mass	Pound	lb
Time	Second	s

Converting Units of length

1 inch (in)= 2.54 cm

1 foot (ft) = 12 in = 30.48 cm

1 yard (yd) = 3 feet = 36 in= 0.9144 m

1 mile (mi) =1760 yards = 5280 feet = 1,609.344 m

1 m = 3.281 ft

Converting Unit of Mass

1 Slug = 32.174 pound-mass (lb)

1 pound (lb) = 453.59 g

1 pound (lb) = 0.45359 kg

1 Slug=14.5909 kg

The atomic mass unit u is

$1\ u = 1.661\times10^{-27}$ kg

Gaussian System of Units (*cgs*)

Physical Quantity	Unit	Symbol
Length	centimeter	cm
Mass	Gram	g
Time	Second	s

Converting Units of length

1 m = 100 cm

1 in = 2.54 cm

1 foot (ft) = 12 in = 30.48 cm

1 yard (yd) = 3 feet = 36 in= 91.44 cm

Converting Unit of Mass

1 kg = 1000 g

1 pound-mass (lb) = 453.59 g

1 Slug=14590.9 g

Conversion factors

Mass conversion factors		Length conversion factors	
1 (kg)	2.21 Pound	1 (in) =	2.54 cm
1 pound (lb)	453.59 g	1 (ft) =	12 in
			0.3048 (m)
Time conversion factors		1 yard (yd) =	3ft = 36 in
1 day	86400 s		0.9144 m
1 year	3.16×10^7 s	1 (mi) =	1760 yd
			5280 ft
			1.609344 (km)
		1 (m)	3.28 (ft)
		1 Light year	9.461×10^{15} (m)

Prefixes

- The standard prefixes are used to designate common multiples in powers of ten.
- For example:
  - $10^6\ m = Mm$
  - $10^3\ m = km$
  - $10^{-3}\ m = mm$
  - $10^{-6}\ m = \mu m$
  - $10^{-9}\ m = nm$
  - Or $1\ m = 10^9\ nm$
  - $1\ angstrom = 10^{-10}\ m$

Power	Prefix	Abbreviation
10^{15}	peta	P
10^{12}	tera	T
10^{9}	giga	G
10^{6}	mega	M
10^{3}	kilo	k
10^{2}	hecto	h
10^{1}	deka	da
10^{-1}	deci	d
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p
10^{-15}	femto	f

The Standard of Time

- Unit of time is second (s)
- Before 1960, the second was originally defined as $\left(\frac{1}{60}\right).\left(\frac{1}{60}\right).(\frac{1}{24})$ of the mean solar day.
- Now: the second (s) is defined as the time required for Cesium (Cs-133) atom to undergo 9,192,631,770 vibration .

Age of the universe	5×10^{17} s
Age of the Earth	1.3×10^{17} s
Existence of human species	6×10^{13} s
Human lifetime	2×10^{9} s
One year	3×10^{7} s
One day	8.6×10^{4} s
Time between heartbeats	0.8 s
Human reaction time	0.1 s
One cycle of a high-pitched sound wave	5×10^{-5} s
One cycle of an AM radio wave	10^{-6} s
One cycle of a visible light wave	2×10^{-15} s

The Standard of Length

- SI Unit of Length: the meter (m)
- in October 1983, the meter (m) was redefined as the distance traveled by light in vacuum during a time of 1/299 792 458 second.

Converting Units of length

- 1 inch (in)= 2.54 cm
- 1 foot (ft) = 12 in = 30.48 cm
- 1 yard (yd) = 3 feet = 36 in= 0.9144 m
- 1 mile (mi) =1760 yards = 5280 feet = 1,609.344 m
- 1 m = 3.281 ft

Typical Length

Distance from Earth to the nearest large galaxy (the Andromeda galaxy, M31)	2×10^{22} m
Diameter of our galaxy (the Milky Way)	8×10^{20} m
Distance from Earth to the nearest star (other than the sun)	4×10^{16} m
One light year	9.46×10^{15} m
Average radius of Pluto's orbit	6×10^{12} m
Distance from Earth to the Sun	1.5×10^{11} m
Radius of Earth	6.37×10^{6} m
Length of a football field	10^{2} m
Height of a person	2 m
Diameter of a CD	0.12 m
Diameter of the aorta	0.018 m
Diameter of a period in a sentence	5×10^{-4} m
Diameter of a red blood cell	8×10^{-6} m
Diameter of the hydrogen atom	10^{-10} m
Diameter of a proton	2×10^{-15} m

Problem 1

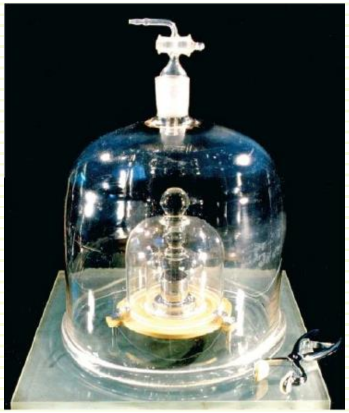
- Any physical quantity can be multiplied by 1 without changing its vale. For example, 1 min= 60 s, so 1 = 60s/1min; similarly, 1 ft=12 in, so 1=1 ft/12 in. Using appropriate conversion factors, find,
- (a) the speed in meters per second equivalent to 55 miles per hour, and
- (b) the volume in cubic centimeters of a tank that holds 16 gallons of gasoline.
- Solution: (a) For our conversion factors, 1 mi =1609 m (so that 1=1609m/1mi) and 1h=3600s (so 1=1h/3600s), thus
- $speed = 55\frac{mi}{h} \times \frac{1609m}{1mi} \times \frac{1h}{3600s} = 25\ m/s$
- (b) One fluid gallon is 231 cubic inches, and 1 in=2.54 cm.
- Thus
- $Volume = 16\ gal \times \frac{231in^3}{1gal} \times \left(\frac{2.54cm}{1in}\right)^3 = 6.1 \times 10^4 cm^3$

Problem 2

- A light-year is a measure of length (not a measure of time) equal to the distance that light travels in 1 year. Compute the conversion factor between light-years and meters, and find the distance to the star Proxima Centauri (4.0 X 10^{16} m) in light-years.
- Solution: The conversion factor from years to second is
- $1y = 1y \times \frac{365.25d}{1y} \times \frac{24h}{1d} \times \frac{60min}{1h} \times \frac{60s}{1min} = 3.16 \times 10^7 s$
- The speed of light is $3.00 \times 10^8 m/s$.
- Thus in 1 year, light travels a distance of
- Distance = velocity x Time = $(3.00 \times 10^8\ m/s)\ (3.16 \times 10^7 s) = 9.48 \times 10^{13}\ m$
- So that
- $1\ light - year = 9.48 \times 10^{13}\ m$
- The distance to Proxima Centauri is
- $(4.0 \times 10^{16} m) \times \frac{1\ light-year}{9.48 \times 10^{13}\ m} = 4.2\ light - years$

The Standard of Mass

- Unit of Mass: kilogram (kg)
- The kilogram (kg), is defined as the mass of a specific platinum–iridium alloy cylinder kept at the International Bureau of Weights and Measures at Sèvres, France.
- This mass standard was established in 1887 and has not been changed since that time because platinum–iridium is an unusually stable alloy.



- **Conversion Unit of Mass**
- The atomic mass unit u is

  $1\ u = 1.661 \times 10^{-27}$ kg

  1 pound (lb) = 453.59 g

Typical Mass

Galaxy (Milky Way)	4×10^{41} kg
Sun	2×10^{30} kg
Earth	5.97×10^{24} kg
Space shuttle	2×10^{6} kg
Elephant	5400 kg
Automobile	1200 kg
Human	70 kg
Baseball	0.15 kg
Honeybee	1.5×10^{-4} kg
Red blood cell	10^{-13} kg
Bacterium	10^{-15} kg
Hydrogen atom	1.67×10^{-27} kg
Electron	9.11×10^{-31} kg

1-7 Dimensional Analysis

- **The dimension in physics** refer to the type of quantity in question regardless of the unit used in the measurement.
- The symbols we use to specify length, mass, and time are L, M, and T, respectively.
- We shall often use brackets [ ] to denote the dimensions of a physical quantity. For example, the nature of speed *v*, is length/time, so the dimension of speed $[v] = L/T$, and nature of the area is length $\times$ length, so the dimension of the area $[A] = L^2$.
- Any valid physical formula must be dimensionally consistent- each term of the formula must have the same dimensions.
- This type of calculation with dimensions is (dimensional analysis).

1-7 Dimensional Analysis

Quantity	The type	Dimension
Distance	Length	L
Area	Length $\times$ Length	L^2
Volume	$(\text{Length})^3$	L^3
Velocity	Length/time	L/T
Acceleration	Length/time^2	L/T^2
Force	Mass $\times$ acceleration	ML/T^2
Pressure	Force/area	$ML/T^2L^2 = M/T^2L$
Density	Mass/volume	M/L^3

Problem 4

- To keep an object moving in a circle at constant speed requires a force called the "centripetal force“. **Use the dimensional analysis to predict the formula of centripetal force F**, if you know that F depends on its mass *m*, its speed *v*, and the radius *r* of its circular path.

Solution:

- Suppose that $F \alpha m^a v^b r^c$
- where the symbol "α" means "is proportional to," and where *a*, *b*, and *c* are numerical exponents to be determined from analyzing the dimensions.
- The dimensions of the left hand side: the force $[F] = MLT^{-2}$

Problem 4

- The dimension of the right hand side $= [m^a]\ [v^b]\ [r^c]$
$= M^a (L/T)^b\ L^c$
- Therefore, $MLT^2 = M^a\ L^{b+c}\ T^{-b}$
- Dimensional consistency means that the fundamental dimensions must be the same on each side. Thus, equating the exponents,

exponent of M : $a = 1$

exponent of T : $b = 2$

exponent of L : $b + c = 1$ so $c = -1$*:*

The resulting expression is $F \propto \frac{mv^2}{r}$

Solved problems

- 1- if you know that the acceleration of gravity in SI unit equals g=9.8 ms^{-2}, find the acceleration in British System of Units.
- Solution:
- Since $1\ m = 3.28\ ft$, then
- $g = 9.80665\ \ ms^{-2} = 9.80665 \times 3.2808\ (ft\ s^{-2}) = 32.174\ ft/s^2$

- 2- if you know that the force is given by Force = Mass × acceleration , find the unit of the force in SI unit and the British system of unit.
- Solution:
- The force $F\ = ma$, the dimension of the force is MLT^{-2}.
- The unit of the force in SI unit is kg.m.s^{-2} which is known as Newton (N).
- In Britch system of unit, we use the expression pound-force which is equal to the gravitational force exerted on a mass of one pound, i.e.,
- 1 Pound-force (1 lbf) = 1 lb (pound-mass) × gravity
- $1\ \text{lbf} = 1\ lb \times 32.174\ (ft/s^2\ ) = 32.174\ \ lb.ft/s^2 = 1\ slug \times ft/s^2$
- $\text{Where } 1\ slug = 32.174\ lb$
- $1\ \text{lbf}\ = 0.45359\ kg \times 9.8\ m/s^2 = 4.4443\ N$

Homework

solve the following questions

1.During a short interval of time the velocity v in m/s of an automobile is given by $v = at^2 + bt^3$, where t is the time in s. the units of a and b are respectively :

A	$m.s^2$	;	$m.s^4$
B	$s^3\ /m$	;	s^4/m
C	m/s^2	;	m/s^3
D	m/s^3	;	m/s^4

2.Suppose $A = BC$,where A has the dimensions L/M and C has the dimensions L/T. Then B has dimension:

A	T/M
B	L^2/TM
C	TM/T^2
D	M/L^2T

3.Suppose $A\ = B^n C^m$, where A has the dimensions LT, B has dimensions L^2T^{-1}, and C has dimensions LT^2. Then the exponents n and m have the values

A	2/3	;	1/3
B	2	;	3
C	4/5	;	0
D	1/5	;	3/5

Homework

solve the following questions

4.Gold, which has a density ($\rho = mass/volume$) of 19.32 g/cm^3, is made as a foil. If a sample of gold, with a mass of 27.63 g, is pressed into a foil of 0.1 cm thickness, what is the area of the foil?

A	14.3 cm^2
B	533.8 cm^2
C	152.2 cm^2
D	8.2 cm^2

5.Gold, which has a density of 19.32 g/cm^3, is made as a thin fiber. If a sample of gold, with a mass of 27.63 g, is drawn out into a cylindrical fiber of radius 0.2500 cm, what is the length of the fiber?

A	1.43 cm
B	7.29 cm
C	19.6 cm
D	15.2 cm

6.A simple pendulum is one which can be considered to be a point mass m is suspended from a string of length L with negligible mass. If we let the pendulum to oscillate with small amplitude, then the period of such a pendulum can be expressed by: $T = K\, m^{a} L^{b} g^{c}$, where K is a dimensionless constant , and g is the acceleration of gravity, then a , b, and c are given respectively by:

A	a = 1 ;	b = 1 ;	c = 1
B	a = 1 ;	b = 1/2 ;	c = -1/2
C	a = 0 ;	b = 1/2 ;	c = -1/2
D	a = 0 ;	b = 1 ;	c = 1