UCH 1201 Principles of Chemical Engineering

Units and Dimensions

Dr. M. Subramanian

Department of Chemical Engineering
SSN College of Engineering

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Contents

Objectives

- To give an overview of common dimensions and units.
- To understand and digest the common unit-conversion factors.

Outcome

- To convert from one system of unit to another for the most common dimensions used in chemical engineering.

Introduction

A dimension is a measure of a physical variable (without numerical values), while a unit is a way to assign a number or measurement to that dimension. For example, length is a dimension, but it is measured in units of feet (ft) or meters (m).

Dimension: A physical entity that can be measured (e.g.: distance)

Unit: Quantitative magnitude of a dimension (e.g.: m)

Unit Systems

The common unit systems in use today:

- International System of Units (SI units, from Le Systeme International d'Unites, more commonly simply called metric units)
- English Engineering System of Units (commonly called English units)

Primary Dimension and Units

Primary (sometimes called basic) dimensions are defined as independent or fundamental dimensions, from which other dimensions can be obtained.

The primary dimensions are: mass, length, time, temperature, amount of matter, electric current, and amount of light. For our chemical engineering analyses, only the first five of these are required.

Primary Dimension	**Symbol**	**SI Unit**	**English Unit**
Mass	m (sometimes M)	kg (kilogram)	lb (pound)
Length	L	m (meter)	ft (foot)
Time	t	s (second)	s
Temperature	T (sometimes θ)	K (Kelvin)	R (Rankine)
Amount of matter	n	mol (mole)	mol

Secondary Dimension and Units

Secondary dimensions are derived from the combination of primary dimensions.

Secondary Dimension	**Symbol**	**SI Unit**	**English Unit**
Velocity	v	m/s	ft/s
Acceleration	a	m/s^2	ft/s^2
Volume	V	m^3	ft^3
Force	$F\ (= ma)$	N (Newton)	lb_f (pound-force)
Pressure	$P\ (= F/A)$	N/m^2	lb_f/in^2 (psi)
Energy, Work	$E\ (= Fd)$	J (Joule = N.m)	ft.lb_f
Power	P	W (= J/s)	ft.lb_f/s

Note that there are many other units, both SI and English, in use today. For example, power is often expressed in units of horsepower, in addition to the standard units of watt. There are conversion factors to enable conversion from any of these units to any other.

Conversion Factors

Length:

1 ft (feet) = 12 in (inch) = 0.3048 m

1 in = 2.54 cm

1 mile = 1.61 km

Area:

$1\ ft^2 = 1 \times (0.3048\ m)^2 = 0.0929\ m^2$

$1\ \text{hectare} = 100\ m \times 100\ m = 10{,}000\ m^2$

$1\ \text{acre} = 66\ ft \times 660\ ft = 43560\ ft^2 = 0.4047\ \text{hectare}$

(66 ft = 1 chain; 660 ft = 1 furlong)

Cents and acres are SI units of measurement of land. 1 acre is equal to 100 cents.

Volume:

$1\ m^3 = 1000$ litre

1 litre = 1000 cm^3 (cc; cubic centimeters) = 1000 milli litre (mL)

1 mL = 1 cm^3

Conversion Factors (contd..)

Temperature:
$^\circ$F= ($^\circ$C$\times$9/5) + 32
1 $^\circ$C rise = 1.8 $^\circ$F rise
-40°C = -40°F
Human body temperature: 98.4°F= 36.9°C.

K (Kelvin) = 273 + $^\circ$C
R (Rankine) = 460 + $^\circ$F
Kelvin and Rankine are absolute temperature scales. i.e., there is no negative K or R values.

Force:
1 kg.m/s^2 = 1 N
1 kg$_f$ = 1 kg $\times$ 9.812 m/s^2 = 9.812 kg.m/s^2 = 9.812 N
1 lb$_f$ = 0.454 kg $\times$ 9.812 m/s^2 = 4.45 kg.m/s^2 = 4.45 N

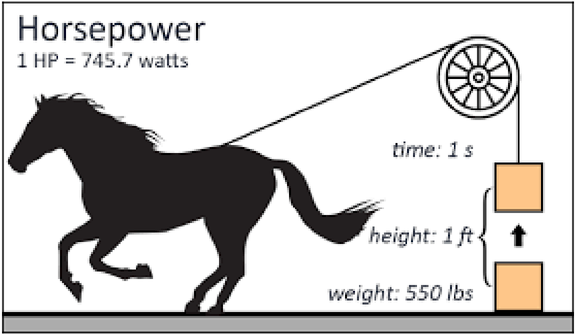
Conversion Factors (contd..)

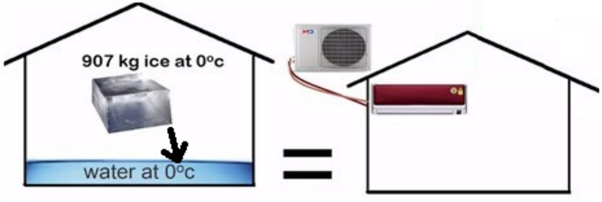
Energy:
1 cal = 4.184 J

About 2500 kcal/day (10 MJ/day) is the per capita food energy requirement of a human-being.

Power:
J/s = W
1 hp (horse power) = 746 W
Typical wind turbine's power rating is 1 MW. The power rating of typical thermal power plant is 1000 MW.

1 ton of refrigeration = 50 kcal/min.
Pressure:
N/m^2 = Pa (Pascal)
1 atm = 1.01325×10^5 N/m^2 = 1.01325 bar = 760 mm Hg


Horsepower
1 HP = 745.7 watts
time: 1 s
height: 1 ft
weight: 550 lbs



1 ton of refrigeration =
Rate of cooling produced by melting
1 short ton (2000 lb) of ice in 24 hours

Metric Prefixes

The following table lists most of the SI prefixes and their values as powers of 10. In the table the abbreviations for the prefix is in bold type and the abbreviation for the basic label is in ordinary text.

Prefix	Value	Example	Description
pico	10^{-12}	**p**m	1 trillionth of a meter
nano	10^{-9}	**n**g	1 billionth of a gram
micro	10^{-6}	μm	1 millionth of a meter
milli	10^{-3}	**m**m	1 thousandth of a meter
kilo	10^{3}	**k**g	1000 grams
Mega	10^{6}	**M**Pa	1 million Pascal
Giga	10^{9}	**G**W	1 billion watts
Tera	10^{12}	**T**B	1 tera bytes
centi	10^{-2}	**c**m	1 hundredth of a meter

Quiz

1. Prove that 1 ton of refrigeration = 50 kcal/min. (Note: 1 ton of refrigeration is the amount of cooling produced by melting 1 short ton (= 2000 lb) of ice in a period of 24 hours. Latent heat of melting of ice = 80 kcal/kg.
2. Calculate the per capita land availability in India in cents/person. (Land area of India = 3.287 million km^2; Human population of India = 1.35 billion in 2020)
3. 1 barrel of crude oil weighs ________ kg.
   1 barrel = 159 litres; density of crude oil = 0.881 g/cc.