

the submultiples of the unit of area are

$$1 \text{ dm}^2 = (1 \text{ dm})^2 = (10^{-1} \text{ m})^2 = 10^{-2} \text{ m}^2$$

$$1 \text{ cm}^2 = (1 \text{ cm})^2 = (10^{-2} \text{ m})^2 = 10^{-4} \text{ m}^2$$

$$1 \text{ mm}^2 = (1 \text{ mm})^2 = (10^{-3} \text{ m})^2 = 10^{-6} \text{ m}^2$$

and the submultiples of the unit of volume are

$$1 \text{ dm}^3 = (1 \text{ dm})^3 = (10^{-1} \text{ m})^3 = 10^{-3} \text{ m}^3$$

$$1 \text{ cm}^3 = (1 \text{ cm})^3 = (10^{-2} \text{ m})^3 = 10^{-6} \text{ m}^3$$

$$1 \text{ mm}^3 = (1 \text{ mm})^3 = (10^{-3} \text{ m})^3 = 10^{-9} \text{ m}^3$$

TABLE 1.2 Principal SI Units Used in Mechanics

Quantity	Unit	Symbol	Formula
Acceleration	Meter per second squared	...	m/s^2
Angle	Radian	rad	†
Angular acceleration	Radian per second squared	...	rad/s^2
Angular velocity	Radian per second	...	rad/s
Area	Square meter	...	m^2
Density	Kilogram per cubic meter	...	kg/m^3
Energy	Joule	J	$\text{N} \cdot \text{m}$
Force	Newton	N	$\text{kg} \cdot \text{m/s}^2$
Frequency	Hertz	Hz	s^{-1}
Impulse	Newton-second	...	$\text{kg} \cdot \text{m/s}$
Length	Meter	m	‡
Mass	Kilogram	kg	‡
Moment of a force	Newton-meter	...	$\text{N} \cdot \text{m}$
Power	Watt	W	J/s
Pressure	Pascal	Pa	N/m^2
Stress	Pascal	Pa	N/m^2
Time	Second	s	‡
Velocity	Meter per second	...	m/s
Volume			
Solids	Cubic meter	...	m^3
Liquids	Liter	L	10^{-3}m^3
Work	Joule	J	$\text{N} \cdot \text{m}$

†Supplementary unit (1 revolution = 2π rad = 360°).

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Length	Meter	m	‡
Mass	Kilogram	kg	‡
Moment of a force	Newton-meter	...	N · m
Power	Watt	W	J/s
Pressure	Pascal	Pa	N/m ²
Stress	Pascal	Pa	N/m ²
Time	Second	s	‡
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Volume			
Solids	Cubic meter	...	m ³
Liquids	Liter	L	10 ⁻³ m ³
Work	Joule	J	N · m

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TABLE 1.3 U.S. Customary Units and Their SI Equivalents

Quantity	U.S. Customary Unit	SI Equivalent	
Acceleration	ft/s ²	0.3048 m/s ²	
	in./s ²	0.0254 m/s ²	
Area	ft ²	0.0929 m ²	
	in ²	645.2 mm ²	
Energy	ft · lb	1.356 J	
Force	kip	4.448 kN	
	lb	4.448 N	
	oz	0.2780 N	
Impulse	lb · s	4.448 N · s	
Length	ft	0.3048 m	
	in.	25.40 mm	
	mi	1.609 km	
Mass	oz mass	28.35 g	
	lb mass	0.4536 kg	
	slug	14.59 kg	
	ton	907.2 kg	
Moment of a force	lb · ft	1.356 N · m	
	lb · in.	0.1130 N · m	
Moment of inertia			
	Of an area	in ⁴	$0.4162 \times 10^6 \text{ mm}^4$
	Of a mass	lb · ft · s ²	1.356 kg · m ²
Momentum	lb · s	4.448 kg · m/s	
Power	ft · lb/s	1.356 W	
	hp	745.7 W	
Pressure or stress	lb/ft ²	47.88 Pa	
	lb/in ² (psi)	6.895 kPa	
Velocity	ft/s	0.3048 m/s	
	in./s	0.0254 m/s	
	mi/h (mph)	0.4470 m/s	
	mi/h (mph)	1.609 km/h	
Volume	ft ³	0.02832 m ³	
	in ³	16.39 cm ³	
	Liquids	gal	3.785 L
	qt	0.9464 L	
Work	ft · lb	1.356 J	

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Method of Problem Solution

- *Problem Statement:*
Includes given data, specification of what is to be determined, and a figure showing all quantities involved.
- *Free-Body Diagrams:*
Create separate diagrams for each of the bodies involved with a clear indication of all forces acting on each body.
- *Fundamental Principles:*
The six fundamental principles are applied to express the conditions of rest or motion of each body. The rules of algebra are applied to solve the equations for the unknown quantities.
- *Solution Check:*
 - Test for errors in reasoning by verifying that the units of the computed results are correct,
 - test for errors in computation by substituting given data and computed results into previously unused equations based on the six principles,
 - **always** apply experience and physical intuition to assess whether results seem “reasonable”

Numerical Accuracy

- The accuracy of a solution depends on 1) accuracy of the given data, and 2) accuracy of the computations performed. The solution cannot be more accurate than the less accurate of these two.
- The use of hand calculators and computers generally makes the accuracy of the computations much greater than the accuracy of the data. Hence, the solution accuracy is usually limited by the data accuracy.
- As a general rule for engineering problems, the data are seldom known with an accuracy greater than 0.2%. Therefore, it is usually appropriate to record parameters beginning with “1” with four digits and with three digits in all other cases, i.e., 40.2 lb and 15.58 lb.

EXAMPLE 1.1

Convert 2 km/h to m/s How many ft/s is this?

SOLUTION

Since 1 km = 1000 m and 1 h = 3600 s, the factors of conversion are arranged in the following order, so that a cancellation of the units can be applied:

$$\begin{aligned} 2 \text{ km/h} &= \frac{2 \text{ km}}{\text{h}} \left(\frac{1000 \text{ m}}{\text{km}} \right) \left(\frac{1 \text{ h}}{3600 \text{ s}} \right) \\ &= \frac{2000 \text{ m}}{3600 \text{ s}} = 0.556 \text{ m/s} \end{aligned} \quad \textit{Ans.}$$

From Table 1-2, 1 ft = 0.3048 m. Thus,

$$\begin{aligned} 0.556 \text{ m/s} &= \left(\frac{0.556 \text{ m}}{\text{s}} \right) \left(\frac{1 \text{ ft}}{0.3048 \text{ m}} \right) \\ &= 1.82 \text{ ft/s} \end{aligned} \quad \textit{Ans.}$$

NOTE: Remember to round off the final answer to three significant figures.

EXAMPLE 1.2

Convert the quantities $300 \text{ lb} \cdot \text{s}$ and $52 \text{ slug}/\text{ft}^3$ to appropriate SI units.

SOLUTION

Using Table 1–2, $1 \text{ lb} = 4.448 2 \text{ N}$.

$$\begin{aligned} 300 \text{ lb} \cdot \text{s} &= 300 \cancel{\text{lb}} \cdot \text{s} \left(\frac{4.448 \text{ N}}{1 \cancel{\text{lb}}} \right) \\ &= 1334.5 \text{ N} \cdot \text{s} = 1.33 \text{ kN} \cdot \text{s} \end{aligned} \quad \textit{Ans.}$$

Since $1 \text{ slug} = 14.593 8 \text{ kg}$ and $1 \text{ ft} = 0.304 8 \text{ m}$, then

$$\begin{aligned} 52 \text{ slug}/\text{ft}^3 &= \frac{52 \cancel{\text{slug}}}{\cancel{\text{ft}}^3} \left(\frac{14.59 \text{ kg}}{1 \cancel{\text{slug}}} \right) \left(\frac{1 \cancel{\text{ft}}}{0.304 8 \text{ m}} \right)^3 \\ &= 26.8(10^3) \text{ kg}/\text{m}^3 \\ &= 26.8 \text{ Mg}/\text{m}^3 \end{aligned} \quad \textit{Ans.}$$

EXAMPLE 1.3

Evaluate each of the following and express with SI units having an appropriate prefix: (a) $(50 \text{ mN})(6 \text{ GN})$, (b) $(400 \text{ mm})(0.6 \text{ MN})^2$, (c) $45 \text{ MN}^3/900 \text{ Gg}$.

SOLUTION

First convert each number to base units, perform the indicated operations, then choose an appropriate prefix.

Part (a)

$$\begin{aligned}(50 \text{ mN})(6 \text{ GN}) &= [50(10^{-3}) \text{ N}][6(10^9) \text{ N}] \\ &= 300(10^6) \text{ N}^2 \\ &= 300(10^6) \text{ N}^2 \left(\frac{1 \text{ kN}}{10^3 \text{ N}} \right) \left(\frac{1 \text{ kN}}{10^3 \text{ N}} \right) \\ &= 300 \text{ kN}^2\end{aligned}$$

Ans.

NOTE: Keep in mind the convention $\text{kN}^2 = (\text{kN})^2 = 10^6 \text{ N}^2$.

Part (b)

$$\begin{aligned}(400 \text{ mm})(0.6 \text{ MN})^2 &= [400(10^{-3}) \text{ m}][0.6(10^6) \text{ N}]^2 \\ &= [400(10^{-3}) \text{ m}][0.36(10^{12}) \text{ N}^2] \\ &= 144(10^9) \text{ m} \cdot \text{N}^2 \\ &= 144 \text{ Gm} \cdot \text{N}^2\end{aligned}$$

Ans.

We can also write

$$\begin{aligned}144(10^9) \text{ m} \cdot \text{N}^2 &= 144(10^9) \text{ m} \cdot \text{N}^2 \left(\frac{1 \text{ MN}}{10^6 \text{ N}} \right) \left(\frac{1 \text{ MN}}{10^6 \text{ N}} \right) \\ &= 0.144 \text{ m} \cdot \text{MN}^2\end{aligned}$$

Ans.

Part (c)

$$\begin{aligned}\frac{45 \text{ MN}^3}{900 \text{ Gg}} &= \frac{45(10^6 \text{ N})^3}{900(10^6) \text{ kg}} \\ &= 50(10^9) \text{ N}^3/\text{kg} \\ &= 50(10^9) \text{ N}^3 \left(\frac{1 \text{ kN}}{10^3 \text{ N}} \right)^3 \frac{1}{\text{kg}} \\ &= 50 \text{ kN}^3/\text{kg}\end{aligned}$$

Ans.

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