جامعة بابل – كلية هندسة المواد –قسم هندسة البوليمرات والصناعات البتروكيمياوية

مبادئ الهندسة الكيمياوية

Principles of Chemical Engineering

المرحلة الثانية

“Units and Dimensions”

(Text Book) الكتاب المقرر

Basic Principles and Calculations in Chemical Engineering, David M. Himmelblua/ James B. Riggs, 7^{th} edition, 2004.

Other references

1-Elementary principles of Chemical processes, Richard M. Felder / Ronald W. Rousseau, 3^{th} edition, 2005.
2-Introduction to Chemical Engineering Processes, Adrian Duncan, 2009.

Course Syllabus المنهاج الدراسي

units and dimensions, Basis, Temperature and pressure, PhChemical engineering equation and stoichiometryysical and chemical properties, Technique of problem solving,, Material Balance without and with chemical reaction, Problem involving tie components, Recycle calculation, Bypass calculation, Purge calculation, Combustion calculation, Ideal gas law, real gas relations.

Dimensions, Units, and their Conversion

1.1Units and Dimensions

The most two commonly used systems of units:

•SI, System International units.

•AE, American Engineering system units.

Dimensions and units are classified to:

•Fundamental (basic) dimensions/units: It can be measured independently and are sufficient to describe essential physical quantities (meter, kilogram, second, Kelvin, mole, .. etc).

•Derived dimensions/units: It can be developed in terms of the fundamental dimensions/units (joule, newton, watt, .. etc).

TABLE 1.1 SI Units Encountered in This Book

Physical Quantity	Name of Unit	Symbol for Unit*	Definition of Unit
	Basic SI Units		
Length	metre, meter	m	
Mass	kilogramme, kilogram	kg	
Time	second	s	
Temperature	kelvin	K	
Molar amount	mole	mol	
	Derived SI Units		
Energy	joule	J	$kg \cdot m^2 \cdot s^{-2} \rightarrow Pa \cdot m^3$
Force	newton	N	$kg \cdot m \cdot s^{-2} \rightarrow J \cdot m^{-1}$
Power	watt	W	$kg \cdot m^2 \cdot s^{-3} \rightarrow J \cdot s^{-1}$
Density	kilogram per cubic meter		$kg \cdot m^{-3}$
Velocity	meter per second		$m \cdot s^{-1}$
Acceleration	meter per second squared		$m \cdot s^{-2}$
Pressure	newton per square meter, pascal		$N \cdot m^{-2}$, Pa
Heat capacity	joule per (kilogram · kelvin)		$J \cdot kg^{-1} \cdot K^{-1}$
	Alternative Units		
Time	minute, hour, day, year	min, h, d, y	
Temperature	degree Celsius	°C	
Volume	litre, liter (dm^3)	L	
Mass	tonne, ton (Mg), gram	t, g	

TABLE 1.2 American Engineering (AE) System Units Encountered in This Book

Physical Quantity	Name of Unit	Symbol
	Some Basic Units	
Length	foot	ft
Mass	pound (mass)	lb_m
Time	second, minute, hour, day	s, min, h (hr), day
Temperature	degree Rankine or degree Fahrenheit	°R or °F
Molar amount	pound mole	lb mol
	Derived Units	
Force	pound (force)	lb_f
Energy	British thermal unit, foot pound (force)	Btu, (ft)(lb_f)
Power	horsepower	hp
Density	pound (mass) per cubic foot	lb_m/ft^3
Velocity	feet per second	ft/s
Acceleration	feet per second squared	ft/s^2
Pressure	pound (force) per square inch	$lb_f/in.^2$, psi
Heat capacity	Btu per pound (mass) per degree F	Btu/(lb_m)(°F)

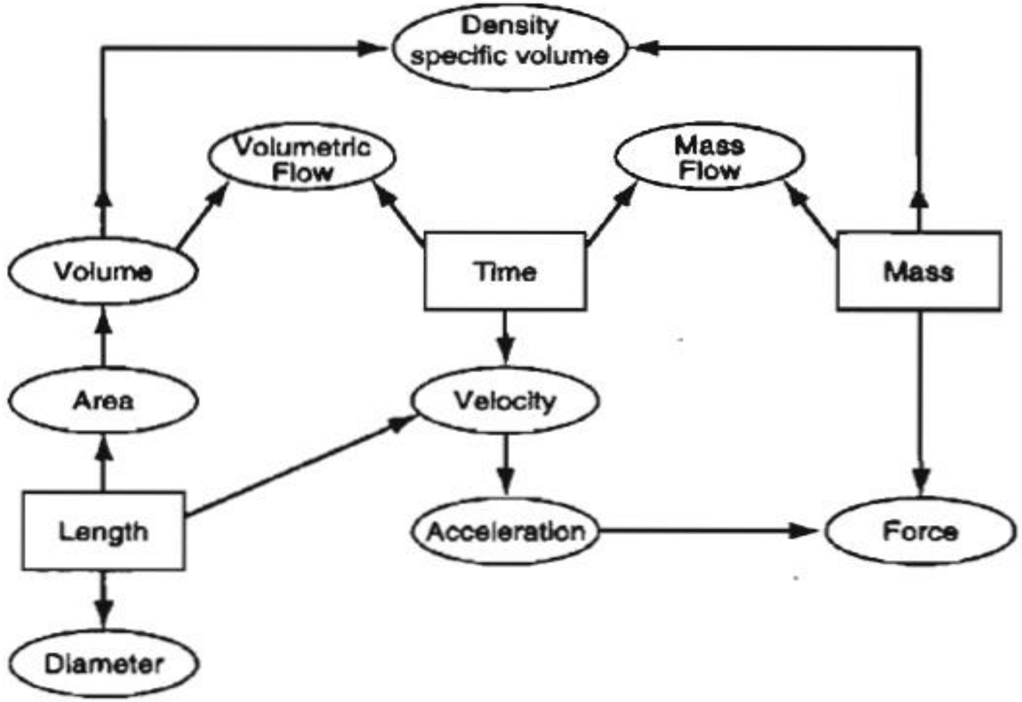


Figure 1.1 Relation between the basic dimensions (in boxes) and various derived dimensions (in ellipses).

TABLE 1.3 SI Prefixes

Factor	Prefix	Symbol	Factor	Prefix	Symbol
10^9	giga	G	10^{-1}	deci	d
10^6	mega	M	10^{-2}	centi	c
10^3	kilo	k	10^{-3}	milli	m
10^2	hecto	h	10^{-6}	micro	μ
10^1	deka	da	10^{-9}	nano	n

Questions

1. What does **ms** mean?

means millisecond.

2. What does **(m) (s)** or **m.s** ?

means meter seconds.

Note: 1 Mm is not 1mm.

3. Which of the following best represents the force needed to lift a heavy suitcase:

a. 25 N

b. 25 kN

c. 250 N

d. 250 kN

4. A watt is:

a. One joule per second

b. equal to 1 (kg)(m^2)/s^2

c. the unit for all types of power

d. all of the above

e. none of the above

5. Is kg/s a basic or derived unit in SI?

Derived unit.

6. Classify the following units as correct or incorrect units in the SI system:

a. nm
b. °K
c. sec
d. N/mm
e. kJ/(s)(m^3)

(a), (d), (e) are correct

1.2 Operations with Units

You can add, subtract, or equate numerical quantities only if the associated units of the quantities are the same. Thus, the operation

5 kilograms + 3 joules

10 pounds + 5 grams

can be performed (because the dimensions are the same, mass) *only* after the units are transformed to be the same, either pounds, grams, or ounces, or some other mass unit.

You can multiply or divide unlike units at will such as

50(kg)(m)/(s)

but you cannot cancel or merge units unless they are identical. Thus, 3 m^2/60 cm

can be converted to 3 m^2/0.6 m, and then to 5 m

EXAMPLE 1.1 Dimensions and Units

Add the following:

(a) 1 foot + 3 seconds
(b) 1 horsepower + 300 watts

Solution

The operation indicated by

$$1 \text{ ft} + 3 \text{ s}$$

has no meaning since the dimensions of the two terms are not the same. One foot has the dimensions of length, whereas 3 seconds has the dimensions of time. In the case of

$$1 \text{ hp} + 300 \text{ watts}$$

the dimensions are the same (energy per unit time), but the units are different. You must transform the two quantities into like units, such as horsepower or watts, before the addition can be carried out. Since 1 hp = 746 watts,

$$746 \text{ watts} + 300 \text{ watts} = 1046 \text{ watts}$$

Questions

1. Answer the following questions yes or no. Can you
   a. divide ft by s?
   b. divide m by cm?
   c. multiply ft by s?
   d. divide ft by cm?
   e. divide m by (deg) K?
   f. add ft and s?
   g. subtract m and (deg) K
   h. add cm and ft?
   i. add cm and m^2?
   j. add 1 and 2 cm?

Solution

(a)-(e) yes

(g)-(j) no

2. Why is it not possible to add 1 ft and 1 ft^2?

The dimensions are not the same

Problems

1. Add 1 cm and 1 m.
2. Subtract 3 ft from 4 yards.
3. Divide 3 $m^{1.5}$ by 2 $m^{0.5}$.
4. Multiply 2 ft by 4 lb.

Solution

1. 101 cm
2. 9 ft
3. 1.5 m
4. 8 (ft)(lb)

1.3 Conversion of Units and Conversion Factors

Example 1.2:

If a plane travels at twice the speed of sound (assume that the speed of sound is 1100 ft/s), how fast is it going in miles per hour?

Solution

$$\frac{2 \times 1100\ \text{ft}}{\text{s}} \left| \frac{1\ \text{mi}}{5280\ \text{ft}} \right| \frac{60\ \text{s}}{1\ \text{min}} \left| \frac{60\ \text{min}}{1\ \text{hr}} \right.$$

$$\frac{\text{ft}}{\text{s}} \qquad \frac{\text{mi}}{\text{s}} \qquad \frac{\text{mi}}{\text{min}}$$

or

$$\frac{2(1100)\ \cancel{\text{ft}}}{\cancel{\text{s}}} \left| \frac{1\ \text{mile}}{5280\ \cancel{\text{ft}}} \right| \frac{60\ \cancel{\text{s}}}{1\ \cancel{\text{min}}} \left| \frac{60\ \cancel{\text{min}}}{1\ \text{hr}} \right.$$

Note:

$$\frac{10\ \text{cm}}{} \left| \frac{2.54\ \text{cm}}{1\ \text{in.}} \right. \neq 25.4\ \text{in., instead of } \frac{10\ \text{cm}}{} \left| \frac{1\ \text{in.}}{2.54\ \text{cm}} \right. = 3.94\ \text{in.}$$

Example 1.3:

(a) Convert 2 km to miles.
(b) Convert 400 $in.^3$/day to cm^3/min.

Solution

(a) One way to carry out the conversion is to look up a direct conversion factor, namely 1.61 km = 1 mile:

$$\frac{2\text{ km}}{}\left|\frac{1\text{ mile}}{1.61\text{ km}}\right. = 1.24\text{ mile}$$

Another way is to use conversion factors you know

$$\frac{2\text{ km}}{}\left|\frac{10^5\text{ cm}}{1\text{ km}}\right|\frac{1\text{ in.}}{2.54\text{ cm}}\left|\frac{1\text{ ft}}{12\text{ in.}}\right|\frac{1\text{ mile}}{5280\text{ ft}} = 1.24\text{ mile}$$

(b) $$\frac{400\text{ in.}^3}{\text{day}}\left|\left(\frac{2.54\text{ cm}}{1\text{ in.}}\right)^3\right|\frac{1\text{ day}}{24\text{ hr}}\left|\frac{1\text{ hr}}{60\text{ min}}\right. = 4.55\frac{\text{cm}^3}{\text{min}}$$

In part (b) note that not only are the numbers in the conversion of inches to centimeters raised to a power, but the units also are raised to the same power.

Example 1.4:

A semiconductor is ZnS with a particle diameter of 1.8 nm, convert this value to (a) dm (decimeters), (b) in (inches).

Solution

(a) $$\frac{1.8 \text{ nm}}{} \left| \frac{10^{-9} \text{ m}}{1 \text{ nm}} \right| \frac{10 \text{ dm}}{1 \text{ m}} = 1.8 \times 10^{-8} \text{ dm}$$

(b) $$\frac{1.8 \text{ nm}}{} \left| \frac{10^{-9} \text{ m}}{1 \text{ nm}} \right| \frac{39.37 \text{ in.}}{1 \text{ m}} = 7.09 \times 10^{-8} \text{ in.}$$

Pound mass (lb_m) and pound force (lb_f)

In the AE system the conversion of terms involving pound **mass** and pound **force** deserve special attention. Let us start the discussion with Newton's Law:

$$F = Cma$$

where F = force
C = a constant whose numerical value and units depend on those selected for F, m, and a
m = mass
a = acceleration

In **SI system** in which the unit of force is defined to be the Newton (N) when 1kg is accelerated at 1 m/s^2, a conversion factor C= 1 N/(kg)(m)/s^2 must be introduced to have the force be 1 N:

$$F = \underbrace{\frac{1\ \text{N}}{\frac{(\text{kg})(\text{m})}{\text{s}^2}}}_{\tilde{C}} \left| \underbrace{\frac{1\ \text{kg}}{}}_{\tilde{m}} \right| \underbrace{\frac{1\ \text{m}}{\text{s}^2}}_{\tilde{a}} = 1\ \text{N}$$

Because the numerical value associated with the conversion factor is 1, the conversion factor seems simple, even nonexistent, and the units are ordinarily ignored.

In the AE system an analogous conversion factor is required. However, to make the numerical value of the force and the mass be essentially the same at the earth's surface, if a mass of 1 lb_m is hypothetically accelerated at g ft/s^2, where g is the acceleration that would be caused by gravity (about 32.2 ft/s^2 depending on the location of the mass), we can make the force be 1 lb_f by choosing the proper numerical value and units for the conversion factor C:

$$F = \underbrace{\left(\frac{1(\text{lb}_f)(s^2)}{32.174(\text{lb}_m)(\text{ft})}\right)}_{\tilde{C}} \left(\underbrace{\frac{1\ \text{lb}_m}{}}_{\tilde{m}} \middle| \underbrace{\frac{g\ \text{ft}}{s^2}}_{\tilde{g}}\right) = 1\ \text{lb}_f$$

A numerical value of 1/32.174 has been chosen for the numerical value in the conversion factor because 32.174 is the numerical value of the average acceleration of gravity (g) (9.80665 m/s^2) at sea level at 45° latitude when g is expressed in ft/s^2. The acceleration caused by gravity, you may recall, varies by a few tenths of 1% from place to place on the surface of the earth but is quite different on the surface of the moon.

The inverse of the conversion factor with the numerical value 32.174 included is given the *special symbol* g_c

$$g_c = 32.174 \frac{(\text{ft})(\text{lb}_m)}{(\text{s}^2)(\text{lb}_f)}$$

	SI	AE
F	N	lb_f
m	kg	lb_m

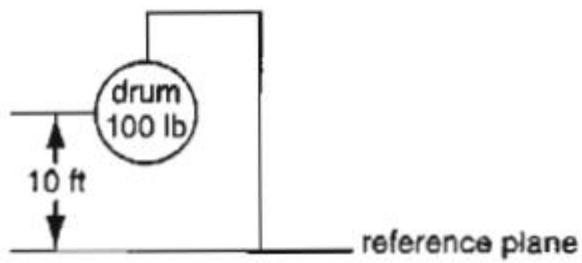
EXAMPLE 1.4 A Conversion Involving Both $1b_m$ and $1b_f$

What is the potential energy in $(ft)(1b_f)$ of a 100 lb drum hanging 10 ft above the surface of the earth with reference to the surface of the earth?

Solution

Potential Energy = P.E= *m g h*

Assume that the 100 lb means 100 lb mass; g = acceleration of gravity = 32.2 ft/s^2. Figure E1.4 is a sketch of the system.



$$P = \frac{100\ \text{lb}_m}{} \left| \frac{32.2\ \text{ft}}{\text{s}^2} \right| \frac{10\ \text{ft}}{} \left| \frac{(\text{s}^2)(\text{lb}_f)}{32.174(\text{ft})(\text{lb}_m)} \right. = 1000\ (\text{ft})(\text{lb}_f)$$

Questions

1. What is g_c?

A conversion factor in the American Engineering system of units.

2. Is the ratio of the numerator and denominator in a conversion factor equal to unity?

Yes

3. What is the difference, if any, between pound force and pound mass in the AE system?

Lb_f is force and lb_m is mass, and the dimensions are different

4. Could a unit of force in the SI system be kilogram force?

The unit is not legal in SI.

5. What is the weight of a one pound mass at sea level? Would the mass be the same at the center of Earth? Would the weight be the same at the center of Earth?

1 lb_f in the AE system of units, yes, no

6. What is the mass of an object that weighs 9.80 kN at sea level?

1000 kg

7.

(a) Which is the correct symbol?

(1) nm (2) °K

(3) sec (4) N/mm

(b) Which is the wrong symbol?

(1) MN/m^2 (2) GHz/s

(3) $kJ/(s)(m^3)$ (4) °C/M/s

(c) Atmospheric pressure is about:

(1) 100 Pa (2) 100 kPa

(3) 10 MPa (4) 1 GPa

(d) The temperature 0°C is defined as:

(1) 273.15°K (2) Absolute zero

(3) 273.15 K (4) The freezing point of water

(e) Which height and mass are those of a petite woman?

(1) 1.50 m, 45 kg (2) 2.00 m, 95 kg

(3) 1.50 m, 75 kg

(a)	N/mm or nm (nanometer)
(b)	°C/M/S
(c)	100 kPa
(d)	2.73.15 K
(e)	1.50m, 45 kg

Problems

1. What are the value and units of g_c in the SI system?
2. Electronic communication via radio travels at approximately the speed of light (186,000 miles/second). The edge of the solar system is roughly at Pluto, which is 3.6×10^9 miles from Earth at its closest approach. How many hours does it take for a radio signal from Earth to reach Pluto?
3. Determine the kinetic energy of one pound of fluid moving in a pipe at the speed of 3 feet per second.
4. Convert the following from AE to SI units:
   a. 4 lb_m/ft to kg/m
   b. 1.00 $lb_m/(ft^3)(s)$ to $kg/(m^3)(s)$
5. Convert the following

$$1.57 \times 10^{-2}\ g/(cm)(s) \text{ to } lb_m/(ft)(s)$$

6. Convert 1.1 gal to ft^3.
7. Convert 1.1 gal to m^3.

Solution

P1. 1, dimensionless
P2. 5.38 hr
P3. 0.14 (ft) (lb_f)
P4. (a) 5.96 kg/m; (b) 16.0 $kg/(m^3)(s)$
P5. $1.06 \times 10^{-3}\ lb_m/(ft)(s)$
P6. 0.15 ft^3
P7. $4.16 \times 10^{-3}\ m^3$

Tutorial (1)

***1.1** Carry out the following conversions:

(a) How many m^3 are there in $1.00(\text{mile})^3$?

(b) How many gal/min correspond to $1.00\ ft^3/s$?

***1.2** Convert

(a) $0.04\ g/(min)(m^3)$ to $lb_m/(hr)(ft^3)$.

(b) 2 L/s to ft^3/day.

(c) $\dfrac{6(\text{in})(\text{cm}^2)}{(\text{yr})(\text{s})(\text{lb}_\text{m})(\text{ft}^2)}$ to all SI units.

Solution

1.1 a. Basis: 1 mi^3

$$\frac{1\,\text{mi}^3}{}\left(\frac{5280\ \text{ft}}{1\ \text{mi}}\right)^3\left(\frac{12\ \text{in}}{1\ \text{ft}}\right)^3\left(\frac{2.54\ \text{cm}}{1\ \text{in}}\right)^3\left(\frac{1\ \text{m}}{100\ \text{cm}}\right)^3 = \boxed{4.17\times10^9\,\text{m}^3}$$

b. Basis: 1 ft^3/s

$$\frac{1\ \text{ft}^3}{1\ \text{s}}\left|\frac{60\ \text{s}}{1\ \text{min}}\right|\frac{7.48\ \text{gal}}{1\ \text{ft}^3} = \boxed{449\ \text{gal/min}}$$

1.2

a.

$$\frac{0.04\ \text{g}}{(\text{min})(\text{m}^3)}\left|\frac{60\ \text{min}}{1\ \text{hr}}\right|\frac{(12\ \text{in})^3}{1\ \text{ft}^3}\left|\frac{1\ \text{lb}_\text{m}}{454\,\text{g}}\right. = \boxed{9.14\frac{\text{lb}_\text{m}}{(\text{hr})(\text{ft}^3)}}$$

b.

$$\frac{2\text{L}}{\text{s}}\left|\frac{3600\ \text{s}}{1\ \text{hr}}\right|\frac{24\ \text{hr}}{1\ \text{day}}\left|\frac{1\ \text{ft}^3}{28.32\text{L}}\right. = \boxed{6.1\times10^3\,\frac{\text{ft}^3}{\text{day}}}$$

c.

$$\frac{6\ (\text{in.})(\text{cm}^2)}{(\text{yr})(\text{s})(\text{lb}_\text{m})(\text{ft}^2)}\left|\frac{1\ \text{ft}^2}{(12\ \text{in})^2}\right|\frac{(1\ \text{in})^2}{(2.54\ \text{cm})^2}\left|\frac{1\ \text{yr}}{365\ \text{days}}\right|\frac{1\ \text{day}}{24\ \text{hr}}\left|\frac{1\ \text{hr}}{3600\text{s}}\right|\frac{2.2\ \text{lb}_\text{m}}{1\ \text{kg}}$$

$$\frac{1\ \text{ft}}{12\ \text{in}}\left|\frac{0.3048\ \text{m}}{1\ \text{ft}}\right. = \boxed{1.14\times10^{-11}\frac{\text{m}}{(\text{kg})(\text{s}^2)}}$$

**1.7 Your boss announced that the speed of the company Boeing 737 is to be cut from 525 mi/hr to 475 mi/hr to "conserve fuel," thus cutting consumption from 2200 gal/hr to 2000 gal/hr. How many gallons are saved in a 1000-mi trip?

Solution

$$\frac{1\text{ hr}}{525\text{ mile}}\left|\frac{2200\text{ gal}}{1\text{ hr}}\right|\frac{1000\text{ mile}}{} = \boxed{4190.5\text{ gal}}$$

$$\frac{1\text{ hr}}{475\text{ mile}}\left|\frac{2000\text{ gal}}{1\text{ hr}}\right|\frac{1000\text{ mile}}{} = \boxed{\frac{4210\text{ gal}}{(20\text{ gal})}}$$

None: 20 gal more are needed.

*1.15 A tractor pulls a load with a force equal to 800 lb (4.0 kN) with a velocity of 300 ft/min (1.5 m/s). What is the power required using the given American Engineering system data? The SI data?

In American Engineering System

Solution

Power = FV

$$= \frac{800\text{ lb}_f}{1}\left|\frac{300\text{ ft}}{\text{min}}\right. = \boxed{2.4\times10^5\ \frac{(\text{lb}_f)(\text{ft})}{\text{min}}} \text{ or } 7.27\text{ hp}$$

In SI

$$\text{Power} = \frac{4000\text{ N}}{1}\left|\frac{1.5\text{ m}}{\text{s}}\right|\frac{1\ (\text{watt})(\text{s})}{1(\text{N})(\text{m})}$$

$$= \boxed{6000\text{ watts}}$$

*1.16 What is the kinetic energy of a vehicle with a mass of 2300 kg moving at the rate of 10.0 ft/sec in Btu? 1 Btu = 778.2 (ft)(lb_f).

Solution

$$KE = \frac{1}{2} m v^2$$

$$= \frac{1}{2} \left| \frac{2300\ kg}{} \right| \frac{1\ lb_m}{0.454\ kg} \left| \left(\frac{10.0\ ft}{s}\right)^2 \right| \frac{1}{\frac{32.2\ lb_m}{lb_f} \left| \frac{ft}{sec^2} \right.} \left| \frac{1\ Btu}{778.2(ft)(lb_f)} \right.$$

$$= \boxed{10.11\ Btu}$$

Conversion Factors

Volume Equivalents

	in.^{3}	ft^3	U.S. gal	liters	m^3
in.^{3}	1	5.787×10^{-4}	4.329×10^{-3}	1.639×10^{-2}	1.639×10^{-5}
ft^3	1.728×10^{3}	1	7.481	28.32	2.832×10^{-2}
U.S. gal	2.31×10^{2}	0.1337	1	3.785	3.785×10^{-3}
liters	61.03	3.531×10^{-2}	0.2642	1	1.000×10^{-3}
m^3	6.102×10^{4}	35.31	264.2	1000	1

Mass Equivalents

	avoir oz	pounds	grains	grams
avoir oz	1	6.25×10^{-2}	4.375×10^{2}	28.35
pounds	16	1	7×10^{3}	4.536×10^{2}
grains	2.286×10^{-3}	1.429×10^{-4}	1	6.48×10^{-2}
grams	3.527×10^{-2}	2.20×10^{-3}	15.432	1

Linear Measure Equivalents

	meter	inch	foot	mile
meter	1	39.37	3.2808	6.214×10^{-4}
inch	2.54×10^{-2}	1	8.333×10^{-2}	1.58×10^{-5}
foot	0.3048	12	1	1.8939×10^{-4}
mile	1.61×10^{3}	6.336×10^{4}	5280	1

Power Equivalents

	hp	kW	$(ft)(lb_f)/s$	Btu/s	J/s
hp	1	0.7457	550	0.7068	7.457×10^{2}
kW	1.341	1	737.56	0.9478	1.000×10^{3}
$(ft)(lb_f)/s$	1.818×10^{-3}	1.356×10^{-3}	1	1.285×10^{-3}	1.356
Btu/s	1.415	1.055	778.16	1	1.055×10^{3}
J/s	1.341×10^{-3}	1.000×10^{-3}	0.7376	9.478×10^{-4}	1

HEAT, ENERGY, OR WORK EQUIVALENTS

	(ft)(lb_f)	kWh	(hp)(hr)	Btu	calorie*	joule
(ft)(lb_f)	1	3.766×10^{-7}	5.0505×10^{-7}	1.285×10^{-3}	0.3241	1.356
kWh	2.655×10^{6}	1	1.341	3.4128×10^{3}	8.6057×10^{5}	3.6×10^{6}
(hp)(hr)	1.98×10^{6}	0.7455	1	2.545×10^{3}	6.4162×10^{5}	2.6845×10^{6}
Btu	7.7816×10^{2}	2.930×10^{-4}	3.930×10^{-4}	1	2.52×10^{2}	1.055×10^{3}
calorie*	3.086	1.162×10^{-6}	1.558×10^{-6}	3.97×10^{-3}	1	4.184
joule	0.7376	2.773×10^{-7}	3.725×10^{-7}	9.484×10^{-4}	0.2390	1

*The thermochemical calorie = 4.184 J.

PRESSURE EQUIVALENTS

	mm Hg	in. Hg	bar	atm	kPa	psia
mm Hg	1	3.937×10^{-2}	1.333×10^{-3}	1.316×10^{-3}	0.1333	1.934×10^{-2}
in. Hg	25.40	1	3.386×10^{1}	3.342×10^{-2}	3.386	0.4912
bar	750.06	29.53	1	0.9869	100.0	14.51
atm	760.0	29.92	1.013	1	101.3	14.696
kPa	7.502	0.2954	1.000×10^{-2}	9.872×10^{-3}	1	0.1451
psia	51.71	2.036	6.893×10^{-2}	6.805×10^{-2}	6.893	1

Ideal Gas Constant R

1.987 cal/(g mol)(K)

1.987 Btu/(lb mol)(°R)

10.73 (psia)(ft^3)/(lb mol)(°R)

8.314 (kPa)(m^3)/(kg mol)(K) = 8.314 J/(g mol)(K)

82.06 (cm^3)(atm)/(g mol)(K)

0.08206 (L)(atm)/(g mol)(K)

21.9 (in Hg)(ft^3)/(lb mol)(°R)

0.7302 (ft^3)(atm)/(lb mol)(°R)

Miscellaneous Conversion Factors

To convert from	To	Multiply by
angstrom	meter	1.000×10^{-10}
barrel (petroleum)	gal	42
centipoise	(newton)(s)/m^2	1.000×10^{-3}
torr (mm Hg, 0°C)	newton/$meter^2$	1.333×10^2
fluid oz	cm^3	29.57