Unit Analysis

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Introduction

Unit analysis converts one unit to another by multiplying by *conversion factors* that equal 1. At each step, the "old" unit *crosses out* with the same unit in the denominator. In this packet, you may assume no outside formulas are needed: every numerical equivalence you need appears either in a local Data Box or in the **Giant Master Table** at the end of this packet. Keep that table open while you work.

How to show your work (always include the units):

1. Write the given quantity with its unit.
2. Multiply by conversion factors written as fractions so that unwanted units cancel.
3. Continue until only the desired unit remains, then compute the number.

Example (with crosses): Converting $1\,\text{day}$ **to seconds**

$$1\,\text{day} \times \frac{24\,\text{h}}{1\,\cancel{\text{day}}} \times \frac{60\,\text{min}}{1\,\cancel{\text{h}}} \times \frac{60\,\text{s}}{1\,\cancel{\text{min}}} = 86{,}400\,\text{s}.$$

Practice

1) A person's height is $5\,\text{ft}\,8\,\text{in}$. Convert to cm and m.

Solution:

$$(5 \times 12 + 8)\,\text{in} = 68\,\text{in} \times \frac{2.54\,\text{cm}}{1\,\cancel{\text{in}}} = 172.72\,\text{cm} = 1.7272\,\text{m}.$$

2) Convert $2.50\,\text{km}$ to mi and to ft.

Solution:

$$2.50\,\text{km} \times \frac{1000\,\text{m}}{1\,\cancel{\text{km}}} \times \frac{1\,\text{mi}}{1609\,\cancel{\text{m}}} = 1.55\,\text{mi}, \quad 2.50\,\text{km} \times \frac{1000\,\text{m}}{1\,\cancel{\text{km}}} \times \frac{3.28084\,\text{ft}}{1\,\cancel{\text{m}}} = 8202\,\text{ft}.$$

3) A jug holds $1.75\,\text{L}$. How many cups and US gallons is this?

Solution:

$$1.75\,\text{L} \times \frac{1000\,\text{mL}}{1\,\cancel{\text{L}}} \times \frac{1\,\text{cup}}{236.588\,\cancel{\text{mL}}} = 7.40\,\text{cups}, \qquad 1.75\,\text{L} \times \frac{1\,\text{gal}}{3.78541\,\cancel{\text{L}}} = 0.462\,\text{gal}.$$

4) Convert $12.0\,\text{lb}$ to kg and g.

Solution:

$$12.0\,\text{lb} \times \frac{453.59237\,\text{g}}{1\,\cancel{\text{lb}}} = 5443.1\,\text{g} = 5.443\,\text{kg}.$$

5) A room is $12\,\text{ft} \times 15\,\text{ft}$. Find its area in m^2.

Solution:

$$A = 180\,\text{ft}^2 \times \frac{1\,\text{m}^2}{10.764\,\cancel{\text{ft}^2}} = 16.7\,\text{m}^2.$$

6) Convert $750\,\text{mL}$ to in^3 and to qt.

Solution:

$$750\,\text{mL} = 750\,\text{cm}^3 \times \frac{1\,\text{in}^3}{16.387\,\cancel{\text{cm}^3}} = 45.8\,\text{in}^3, \quad 750\,\text{mL} \times \frac{1\,\text{L}}{1000\,\cancel{\text{mL}}} \times \frac{1\,\text{qt}}{0.94635\,\cancel{\text{L}}} = 0.792\,\text{qt}.$$

7) Convert $3.25\,\text{ft}^3/\text{min}$ to L/s.

Solution:

$$3.25\,\frac{\text{ft}^3}{\text{min}} \times \frac{28.3168\,\text{L}}{1\,\cancel{\text{ft}^3}} \times \frac{1\,\text{min}}{60\,\text{s}} = 1.54\,\text{L/s}.$$

8) A warm room is 72°F. Convert to °C and K.

Solution:

$$^\circ\text{C} = \frac{5}{9}(72 - 32) = 22.2^\circ\text{C}, \qquad \text{K} = 22.2 + 273.15 = 295.35\,\text{K}.$$

9) Convert $35.0\,\text{psi}$ to kPa and bar.

Solution:

$$35.0\,\text{psi} \times \frac{6894.757\,\text{Pa}}{1\,\cancel{\text{psi}}} = 241{,}316\,\text{Pa} = 241.3\,\text{kPa}, \quad 241{,}316\,\text{Pa} \times \frac{1\,\text{bar}}{100{,}000\,\cancel{\text{Pa}}} = 2.41\,\text{bar}.$$

10) A shower flows at 12.0 L/min. Convert to gal/min and to ft^3/h.

Solution:

$$12.0\,\frac{\text{L}}{\text{min}} \times \frac{1\,\text{gal}}{3.78541\,\cancel{\text{L}}} = 3.17\,\text{gal/min}, \quad 12.0\,\frac{\text{L}}{\text{min}} \times \frac{1\,\text{m}^3}{1000\,\cancel{\text{L}}} \times \frac{35.3147\,\text{ft}^3}{1\,\cancel{\text{m}^3}} \times 60\,\frac{\text{min}}{\text{h}} = 25.4\,\text{ft}^3/\text{h}.$$

11) A car's fuel economy is 7.50 L/100 km. Convert to mpg (US).

Solution:

$$7.50\,\frac{\text{L}}{100\,\text{km}} \times \frac{1\,\text{gal}}{3.78541\,\cancel{\text{L}}} = 1.981\,\frac{\text{gal}}{100\,\text{km}},$$

$$\frac{\text{gal}}{\text{mi}} = 1.981\,\frac{\text{gal}}{100\,\text{km}} \times \frac{1.609\,\text{km}}{1\,\text{mi}} = 0.0319\,\frac{\text{gal}}{\text{mi}}, \qquad \text{mpg} = \frac{1}{0.0319} = 31.4\,\text{mpg}.$$

12) On a trip you average 90.0 km/h for 2.25 h. How far is this in miles?

Solution:

$$d = vt = 90.0\,\frac{\text{km}}{\text{h}} \times 2.25\,\text{h} = 202.5\,\text{km} \times \frac{1\,\text{mi}}{1.609\,\cancel{\text{km}}} = 126\,\text{mi}.$$

13) A runner covers 3.20 km in 18.0 min. Find average speed in m/s and km/h.

Solution:

$$v = \frac{d}{t} = \frac{3.20\,\text{km}}{18.0\,\text{min}} = \frac{3200\,\text{m}}{1080\,\text{s}} = 2.96\,\text{m/s}, \quad 2.96\,\text{m/s} \times \frac{3600\,\text{s}}{1000\,\text{m}} = 10.7\,\text{km/h}.$$

14) A cyclist rides at 24 km/h. How many minutes to travel 7.5 km?

Solution:

$$t = \frac{d}{v} = \frac{7.5\,\text{km}}{24\,\text{km/h}} = 0.3125\,\text{h} \times 60\,\frac{\text{min}}{\text{h}} = 18.8\,\text{min}.$$

15) A car goes 65 mph for 45 min. How far in km?

Solution:

$$t = 45\,\text{min} = 0.75\,\text{h}, \quad d = vt = 65\,\text{mi/h} \times 0.75\,\text{h} = 48.75\,\text{mi} \times 1.609\,\frac{\text{km}}{\text{mi}} = 78.5\,\text{km}.$$

16) A metal sample has mass 540 g and volume 400 cm^3. Find density in g/cm^3 and kg/m^3.

Solution:

$$\rho = \frac{m}{V} = \frac{540\,\text{g}}{400\,\text{cm}^3} = 1.35\,\text{g/cm}^3, \quad 1.35\,\text{g/cm}^3 = 1.35 \times 1000 = 1350\,\text{kg/m}^3.$$

17) Cooking oil has density 0.92 g/mL. What is the mass of 2.50 L of oil in kg?

Solution:

$$V = 2.50\,\text{L} = 2500\,\text{mL}, \quad m = \rho V = 0.92\,\frac{\text{g}}{\text{mL}} \times 2500\,\text{mL} = 2300\,\text{g} = 2.30\,\text{kg}.$$

18) A wood block has density $0.60\,\text{g/cm}^3$ and mass 900 g. Find its volume in cm^3 and mL.

Solution:

$$V = \frac{m}{\rho} = \frac{900\,\text{g}}{0.60\,\text{g/cm}^3} = 1500\,\text{cm}^3 = 1500\,\text{mL}.$$

19) Convert 4.5 mi to km and m.

Solution:

$$4.5\,\text{mi} \times 1.609\,\frac{\text{km}}{1\,\cancel{\text{mi}}} = 7.24\,\text{km} = 7.24 \times 1000 = 7240\,\text{m}.$$

20) A recipe calls for 3.0 tsp (teaspoons). Convert to mL and tbsp (1 tbsp = 3 tsp, 1 tsp = 4.92892 mL).

Solution:

$$3.0\,\text{tsp} \times 4.92892\,\frac{\text{mL}}{1\,\cancel{\text{tsp}}} = 14.8\,\text{mL}, \qquad 3.0\,\text{tsp} \times \frac{1\,\text{tbsp}}{3\,\cancel{\text{tsp}}} = 1.0\,\text{tbsp}.$$

21) Convert $0.85\,\text{m}^3$ to L and US gal.

Solution:

$$0.85\,\text{m}^3 \times \frac{1000\,\text{L}}{1\,\cancel{\text{m}^3}} = 850\,\text{L}, \qquad 850\,\text{L} \times \frac{1\,\text{gal}}{3.78541\,\cancel{\text{L}}} = 225\,\text{gal}.$$

22) Convert 3.6 m/s to km/h and mph.

Solution:

$$3.6\,\frac{\text{m}}{\text{s}} \times \frac{3600\,\text{s}}{1000\,\text{m}} = 12.96\,\text{km/h}, \qquad 12.96\,\text{km/h} \times \frac{0.621371\,\text{mi}}{1\,\cancel{\text{km}}} = 8.05\,\text{mph}.$$

23) A bottle is 355 mL. Express this in fl oz (US) and in cups (1 fl oz = 29.5735 mL).

Solution:

$$355\,\text{mL} \times \frac{1\,\text{fl oz}}{29.5735\,\cancel{\text{mL}}} = 12.0\,\text{fl oz}, \qquad 12.0\,\text{fl oz} \times \frac{1\,\text{cup}}{8\,\cancel{\text{fl oz}}} = 1.50\,\text{cups}.$$

24) Convert $1.25\,\text{yd}^2$ to m^2 and ft^2.

Solution:

$$1.25\,\text{yd}^2 \times \frac{9\,\text{ft}^2}{1\,\cancel{\text{yd}^2}} = 11.25\,\text{ft}^2, \qquad 1.25\,\text{yd}^2 \times (0.9144\,\text{m})^2 = 1.05\,\text{m}^2.$$

Unit Analysis — Master Table

SI Prefixes (Name, Symbol, Factor)
milli m 10^{-3}
centi c 10^{-2}
kilo k 10^{3}

Time
$60\,\text{s} = 1\,\text{min}$; $60\,\text{min} = 1\,\text{h}$; $24\,\text{h} = 1\,\text{day}$

Length
$1\,\text{in} = 2.54\,\text{cm}$ *exact*
$12\,\text{in} = 1\,\text{ft}$; $3\,\text{ft} = 1\,\text{yd}$; $5280\,\text{ft} = 1\,\text{mi}$
$1\,\text{km} = 1000\,\text{m}$; $1\,\text{mi} = 1609\,\text{m} \approx 1.609\,\text{km}$
$1\,\text{m} = 3.28084\,\text{ft}$

Area
$1\,\text{m}^2 \approx 10.764\,\text{ft}^2$; $1\,\text{cm}^2 \approx 0.1550\,\text{in}^2$; $1\,\text{yd}^2 = 9\,\text{ft}^2$

Volume
$1\,\text{L} = 1000\,\text{mL} = 1000\,\text{cm}^3$
$1\,\text{m}^3 = 1000\,\text{L}$
$1\,\text{in}^3 = 16.387\,\text{cm}^3$; $1\,\text{ft}^3 = 28.3168\,\text{L}$
$1\,\text{gal (US)} = 3.78541\,\text{L}$; $1\,\text{qt} = 0.94635\,\text{L}$
$1\,\text{cup} = 236.588\,\text{mL}$; $1\,\text{fl oz} = 29.5735\,\text{mL}$
$1\,\text{tbsp} = 3\,\text{tsp}$; $1\,\text{tsp} = 4.92892\,\text{mL}$

Mass & Density
$1\,\text{kg} = 1000\,\text{g}$; $1\,\text{lb} = 453.59237\,\text{g}$ *exact*
$\rho = \dfrac{m}{V}$; Water $\approx 1.00\,\text{g/cm}^3 = 1000\,\text{kg/m}^3$

Pressure
$1\,\text{psi} = 6894.757\,\text{Pa}$; $1\,\text{kPa} = 1000\,\text{Pa}$; $1\,\text{bar} = 100{,}000\,\text{Pa}$

Speed (Grade 8/9)
$v = \dfrac{d}{t}$; $d = vt$; $t = \dfrac{d}{v}$
$1\,\text{km/h} = \dfrac{1000}{3600}\,\text{m/s} \approx 0.2778\,\text{m/s}$; $1\,\text{mph} \approx 1.609\,\text{km/h}$

Temperature
$^\circ\text{C} = \dfrac{5}{9}(^\circ\text{F} - 32)$; $\text{K} = ^\circ\text{C} + 273.15$