CE 107 : Introduction to Civil and Environmental Engineering

Lecture 2: Unit Conversions

International System of Units (SI) (MKS system)

Fundamental Dimensions:

Length = m

Mass = kg

Time = s

Derived Dimensions:

Force = N (newton) = $kg*m/s_2$

Energy = J (joule) = N*m

Power = W (watt) = J/s

FPS System

Fundamental Dimensions:

- Length = ft
- Force = lb_f
- Time = s

Derived Dimensions:

- Mass = slug = lb_f*s_2/ft = 32.174 lb_m
- Energy = $ft*lb_f$
- Power = $ft*lb_f/s$

A. SI Prefix Conversions

move left

move right

Prefix	Symbol	Factor
mega-	M	10^{6}
kilo-	k	10^{3}
BASE UNIT	---	10^{0}
deci-	d	10^{-1}
centi-	c	10^{-2}
milli-	m	10^{-3}
micro-	μ	10^{-6}
nano-	n	10^{-9}
pico-	p	10^{-12}

A. SI Prefix Conversions

1) 20 cm = _____ m

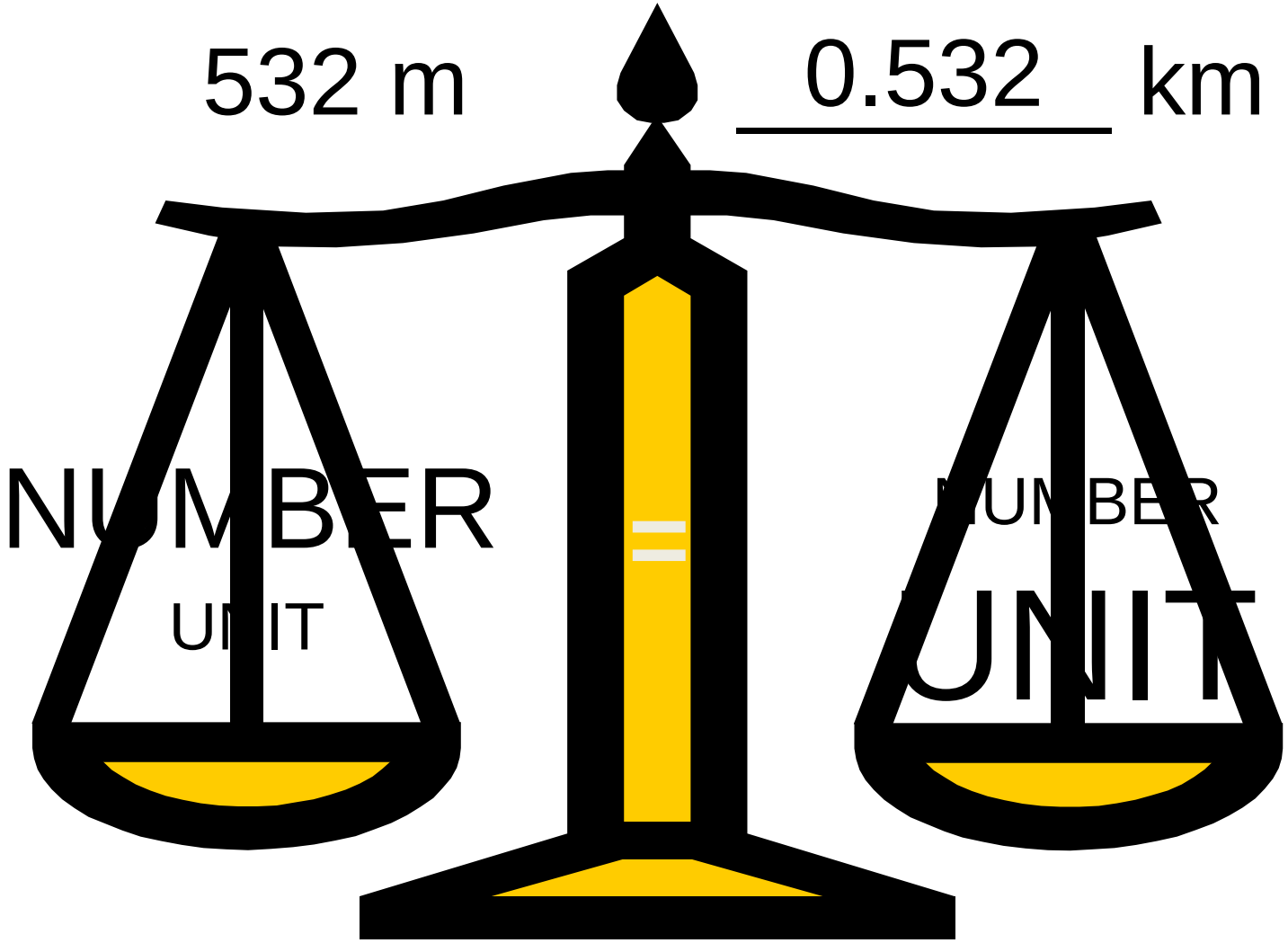
2) 0.032 L = _____ mL

3) 45 μm = _____ nm

4) 805 dm = _____ km

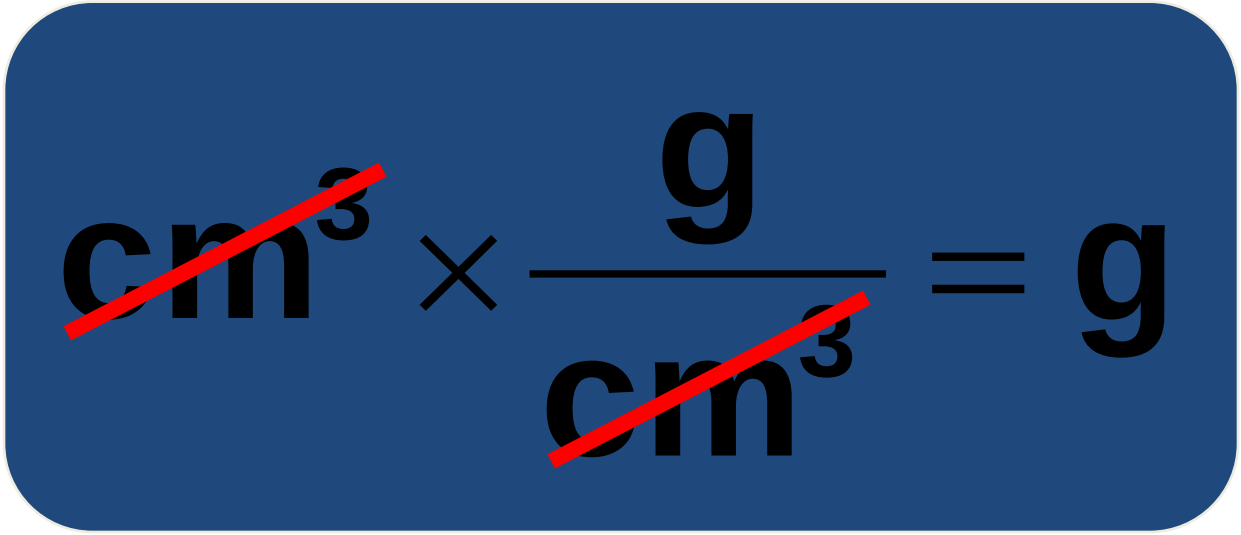
A. SI Prefix Conversions

532 m = 0.532 km



B. Dimensional Analysis

- The "Factor-Label" Method
  - Units, or "labels" are canceled, or "factored" out



Converting Units

- **Factor label method**
  - Regardless of conversion, keeping track of units makes things come out right
  - Must use conversion factors
    - ✧- The relationship between two units
  - Canceling out units is a way of checking that your calculation is set up right!

B. Dimensional Analysis

- Steps:
  1. Identify starting & ending units.
  2. Line up conversion factors so units cancel.
  3. Multiply all top numbers & divide by each bottom number.
  4. Check units & answer.

Common Conversion Factors

English	**Factor**
1 gallon = 4 quarts	4 qt/gal or 1gal/4 qt
1 mile = 5280 feet	5280 ft/mile or 1 mile/5280 ft
1 ton = 2000 pounds	2000 lb/ton or 1 ton/2000 lb

- Common English to Metric
- 1 liter = 1.057 quarts 1.057 qt/L or 1 L/1.057 qt
  or 0.946 L/qt
- 1 kilogram = 2.2 pounds 2.2 lb/kg or 1 kg/2.2 lb
- or 0.454 kg/lb
- 1 meter = 1.094 yards 1.094 yd/m or 1m/1.094 yd
- or 0.917m/yd
- 1 inch = 2.54 cm 2.54 cm/inch or 1 in/2.54 cm

B. Dimensional Analysis

- Lining up conversion factors:

$$\frac{1\text{ in}}{2.54\text{ cm}} = 1$$

$$1 = \frac{2.54\text{ cm}}{1\text{ in}}$$

Line Mole Method

- Process to convert from one unit to another
- Example: Convert 3.00 m to inch:

$$? = 3.00\ \text{m} \quad \frac{100\ \text{cm}}{1\ \text{m}} \quad \frac{1\ \text{in}}{2.54\ \text{cm}}$$

ANSWER = 118 in

Line Mole Method

- Process to convert from one unit to another
- Example: Convert 3.00 m/s to m/hr:

$$? = 3.00\ \frac{m}{s}\ \frac{60\ s}{min}\ \frac{60\ min}{hr}$$

ANSWER = 10,800 m/hr

Example: Metric Conversion

How many milligrams are in a kilogram?

$$1kg = 1000g$$

$$1g = 1000mg$$

$$1kg \times \frac{1000g}{1kg} \times \frac{1000mg}{g} = 1{,}000{,}000mg$$

B. Dimensional Analysis

- How many milliliters are in 1.00 quart of milk?

qt mL

$$\frac{1.00\ \text{qt}}{1.057\ \text{qt}} \times \frac{1\ \text{L}}{1\ \text{L}} \times \frac{1000\ \text{mL}}{1} = 946\ \text{mL}$$

B. Dimensional Analysis

- How many milliliters are in 1.00 quart of milk?

qt mL

$$\frac{1.00\ \text{qt}}{1.057\ \text{qt}} \times \frac{1\ \text{L}}{1\ \text{L}} \times \frac{1000\ \text{mL}}{1} = 946\ \text{mL}$$

B. Dimensional Analysis

- You have 1.5 pounds of gold. Find its volume in cm^3 if the density of gold is 19.3 g/cm^3.

lb **cm^3**

$$\frac{1.5\ \cancel{lb} \mid 1\ \cancel{kg} \mid 1000\ \cancel{g} \mid 1\ cm^3}{\quad \mid 2.2\ \cancel{lb} \mid 1\ \cancel{kg} \mid 19.3\ \cancel{g}} = 35\ cm^3$$

B. Dimensional Analysis

- How many liters of water would fill a container that measures 75.0 in^3?

in^3 **L**

$$\frac{75.0\ \cancel{in^3} \mid (2.54\ \cancel{cm})^3 \mid 1\ L}{\mid (1\ \cancel{in})^3 \mid 1000\ \cancel{cm^3}} = 1.23\ L$$

B. Dimensional Analysis

5) Your European hairdresser wants to cut your hair 8.0 cm shorter. How many inches will he be cutting off?

cm **in**

$$\frac{8.0\ \text{cm} \mid 1\ \text{in}}{\mid\ 2.54\ \text{cm}} = 3.1\ \text{in}$$

Converting Area and Volume

Caution: Make sure the units cancel

Area: 150 ft^2 to yd^2

$$150\ ft^2 \left| \frac{1\ yd}{3\ ft} \right| \frac{1\ yd}{3\ ft}$$

OR

$$150\ ft^2 \left| \frac{(10)2\ yd2}{(3)^2\ ft^2} \right.$$

Volume: 12 ft^3 to Liters

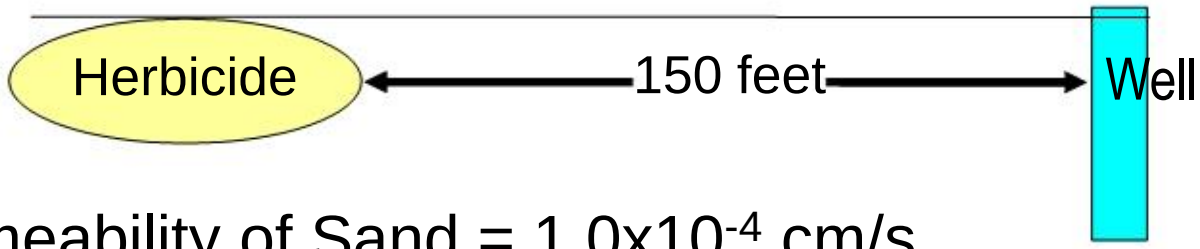
$$12\ ft^3 \left| \frac{(12)^3\ in^3}{(1)^3\ ft^3} \right| \frac{(2.54)^3\ cm^3}{(1)^3\ in^3} \left| \frac{(1)^3\ m^3}{(100)^3\ cm^3} \right| \frac{1000\ L}{1\ m^3}$$

Chemical Herbicide Spill
Line Mole Method - Example

Problem:

The permeability of sand is 1.0×10^{-4} cm/s. If a chemical herbicide is dumped on a sandy soil, how long (in hours) will it take for the contaminant to reach the well 150 feet away.

Diagram:



Permeability of Sand = 1.0×10^{-4} cm/s
t = Time (hours)
1.0×10^{-4} cm/s = __?__ ft/hr

Chemical Herbicide Spill

Line Mole Method - Example

Solution:

Permeability = 0.011811 ft/hr

Time = Distance / Permeability

$$t = \frac{150 \text{ ft}}{0.011811 \text{ ft/hr}} \quad \text{OR} \quad t = 150 \text{ ft} \left| \frac{\text{hr}}{0.011811 \text{ ft}} \right.$$

t = 12700 hours = 13000 hours

How many years is that?

$$t = 12700 \text{ hr} \left| \frac{1 \text{ day}}{24 \text{ hr}} \right| \frac{1 \text{ yr}}{365 \text{ day}} = 1.4 \text{ yr}$$

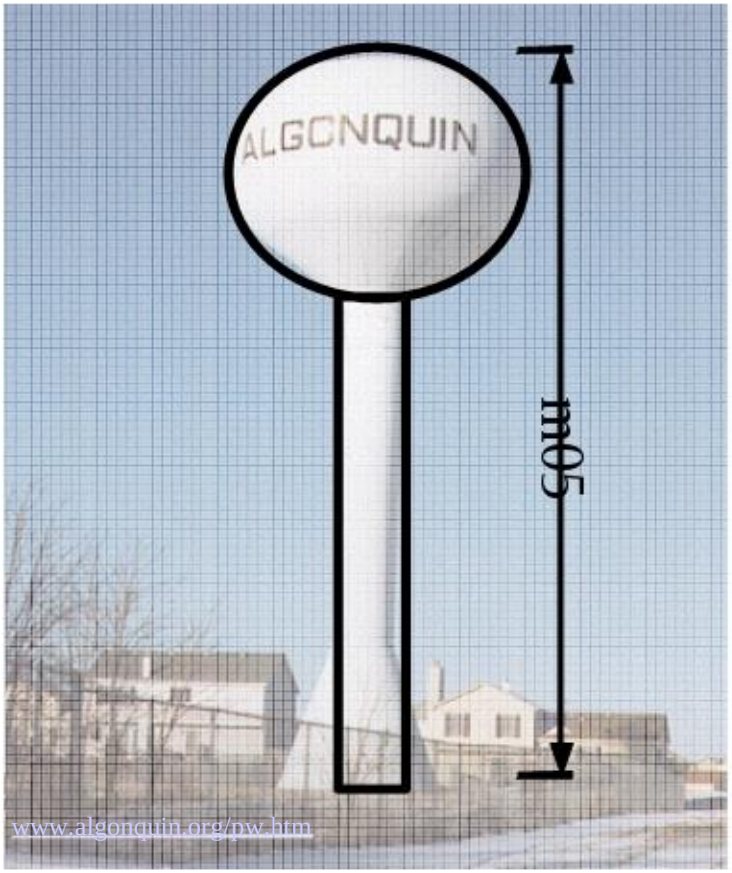
As an individual, solve...
Water Tower Problem

Problem Statement:

- Your home town is growing so rapidly that another water tower is necessary to meet the needs of the community. Civil and environmental engineers predict that the water tower will need to hold 1.00 x 10.0^6 kilograms of water. The engineers also estimate the density of the water to be 999 kilograms per cubic meter.
- If this tower is 50.0 meters high and spherical, what volume (gal) of water will the tower hold and what will the diameter (ft) of the tower have to be?

Diagram:

- mass of water = 1.00×10^6 kg
- density of water = 999 kg/m^3
- tower height = 50.0 m
  - ? volume of water (L)
  - ? diameter (ft)



Theory:

Volume of a sphere $= \frac{4}{3}\pi r^3$

diameter $= 2r = \sqrt[3]{\frac{3V}{4\pi}}$

Assumptions:

- tower is spherical

Solution:

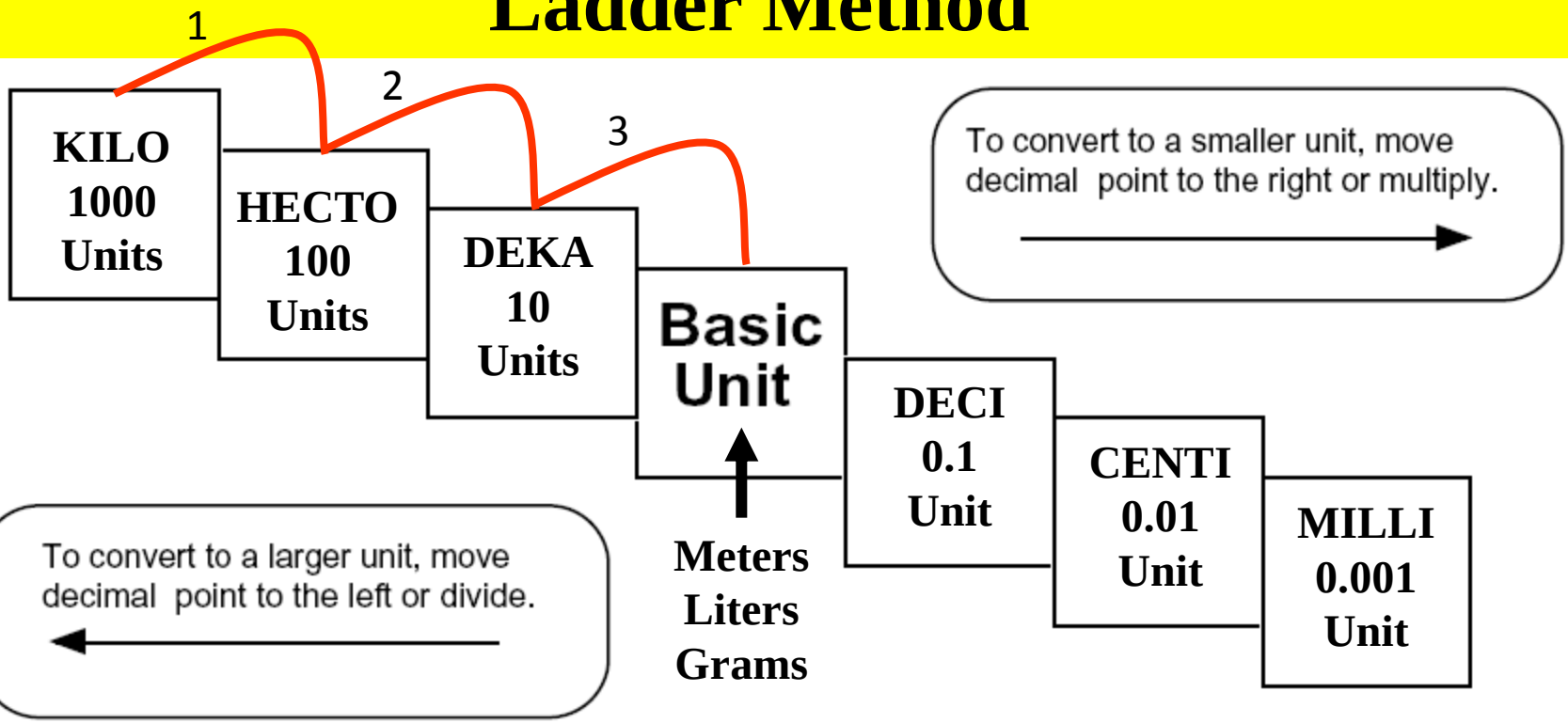
$$\text{volume of water} = \frac{1.00 \times 10^6 \text{ kg} \mid 1 \text{ m}^3 \mid 1000 \text{ L}}{999 \text{ kg} \mid 1 \text{ m}^3} = 1.00 \times 10^6 \text{ L}$$

$$\textit{Volume of a sphere} = \frac{4}{3}\pi r^3 \qquad \textit{diameter} = 2r = \sqrt[3]{\frac{3V}{4\pi}}$$

$$\text{volume of water} = \frac{1.00 \times 10^6 \text{ L} \mid 0.035315 \text{ ft}^3}{1 \text{ L}} = 3.53 \times 10^4 \text{ ft}^3$$

$$\textit{diameter} = 2r = \sqrt[3]{\frac{3 * 3.53 \times 10^4 \textit{ ft}^3}{4\pi}} = 40.7 \textit{ ft}$$

Ladder Method



How do you use the "ladder" method?

1st – Determine your starting point.

2nd – Count the "jumps" to your ending point.

3rd – Move the decimal the same number of jumps in the same direction.

4 km = _____ m

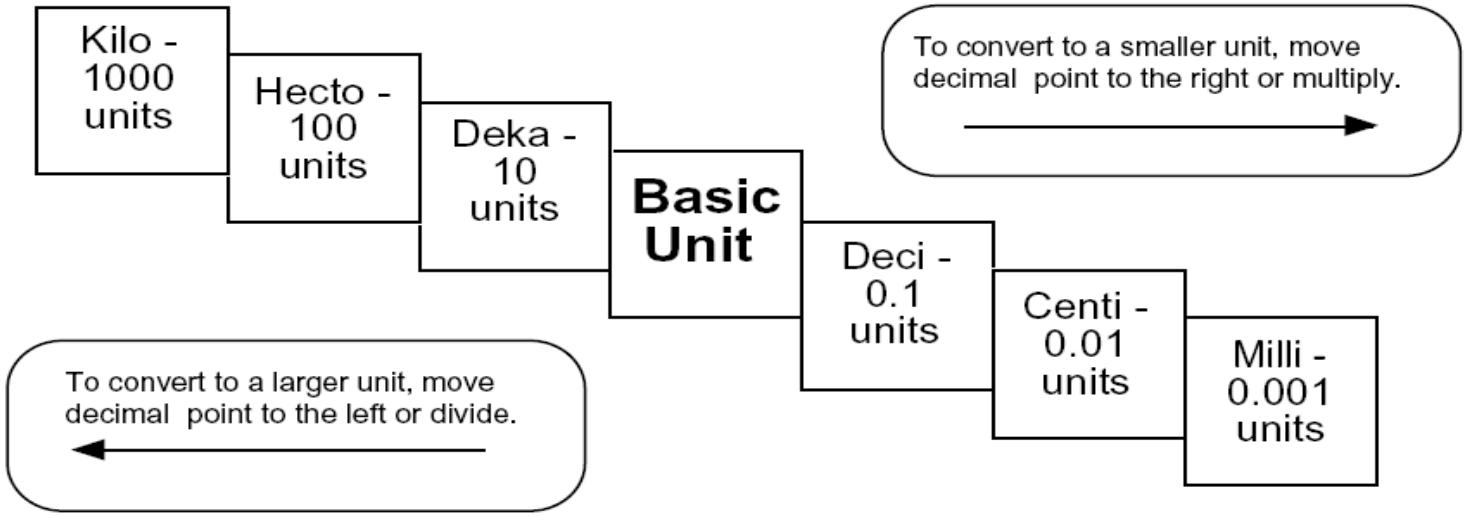
Starting Point Ending Point

How many jumps does it take?

4. _. _. _. = 4000 m

1 2 3

Conversion Practice



Try these conversions using the ladder method.

1000 mg = _____ g 1 L = _____ mL 160 cm = _____ mm

14 km = _____ m 109 g = _____ kg 250 m = _____ km

Compare using <, >, or =.

56 cm (6 m) 7 g ( ) 698 mg

Metric Conversion Challenge

Write the correct abbreviation for each metric unit.

1) Kilogram _____ 4) Milliliter _____ 7) Kilometer _____

2) Meter _____ 5) Millimeter _____ 8) Centimeter _____

3) Gram _____ 6) Liter _____ 9) Milligram _____

Try these conversions, using the ladder method.

10) 2000 mg = _____ g 15) 5 L = _____ mL 20) 16 cm = _____ mm

11) 104 km = _____ m 16) 198 g = _____ kg 21) 2500 m = _____ km

12) 480 cm = _____ m 17) 75 mL = _____ L 22) 65 g = _____ mg

13) 5.6 kg = _____ g 18) 50 cm = _____ m 23) 6.3 cm = _____ mm

14) 8 mm = _____ cm 19) 5.6 m = _____ cm 24) 120 mg = _____ g

Compare using <, >, or =.

25) 63 cm ◯ 6 m

26) 536 cm ◯ 53.6 dm

27) 5 g ◯ 508 mg

28) 43 mg ◯ 5 g

29) 1,500 mL ◯ 1.5 L

30) 3.6 m ◯ 36 cm

Example Problem

Measured dimensions of a rectangle:

length (L) = 9.70 cm

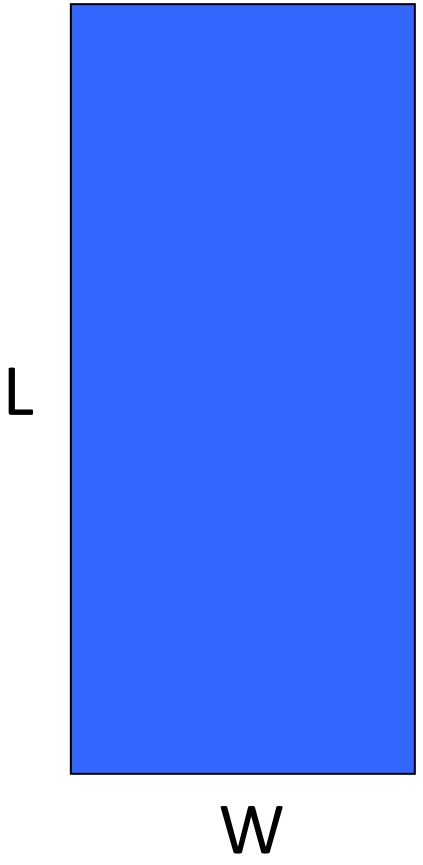
width (W) = 4.25 cm

Find area of rectangle.

$A = L \cdot W$

$= (9.70\ \text{cm})(4.25\ \text{cm})$

$= 41.2\ \text{cm}^2 \cdot \text{cm}$



Convert 41.2 cm^2 to m^2.

$X\ m^2 = 41.2\ cm^2 \left(\frac{1\ m}{100\ cm}\right) = 0.412\ m^2$ WRONG!

$= 0.412\ cm \cdot m$

Recall that… $41.2\ cm^2 = 41.2\ cm \cdot cm$

$X\ m^2 = 41.2\ cm \cdot cm \left(\frac{1\ m}{100\ cm}\right)\left(\frac{1\ m}{100\ cm}\right)$

$= 0.00412\ m^2$

$X\ m^2 = 41.2\ cm^2 \left(\frac{1\ m}{100\ cm}\right)^2 = 0.00412\ m^2$

Convert 41.2 cm^2 to mm^2.

Recall that… 41.2 cm^2 = 41.2 cm·cm

$$X\ mm^2 = 41.2\ cm \cdot cm \left(\frac{10\ mm}{1\ cm}\right)\left(\frac{10\ mm}{1\ cm}\right)$$

$$= \boxed{4{,}120\ mm^2}$$

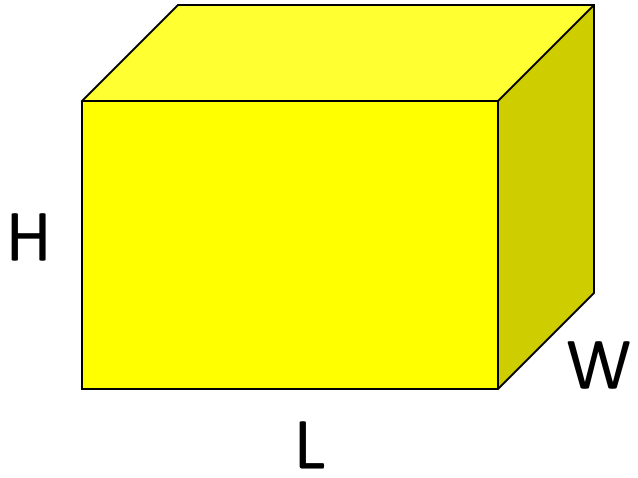
$$X\ mm^2 = 41.2\ cm^2 \left(\frac{10\ mm}{1\ cm}\right)^2 = \boxed{4{,}120\ mm^2}$$

Measured dimensions of a rectangular solid:

Length = 15.2 cm

Width = 3.7 cm

Height = 8.6 cm



Find volume of solid.

$$V = L \cdot W \cdot H$$

$$= (15.2\ \text{cm})(3.7\ \text{cm})(8.6\ \text{cm})$$

$$= 480\ \text{cm}^3$$

Convert to m^3.

$$X\ m^3 = 480\ \cancel{cm \cdot cm \cdot cm}\ cm^3 \left(\frac{1\ m}{100\ \cancel{cm}}\right)\left(\frac{1\ m}{100\ \cancel{cm}}\right)\left(\frac{1\ m}{100\ \cancel{cm}}\right) =$$

or

$$X\ m^3 = 480\ cm^3 \left(\frac{1\ m}{100\ cm}\right)^3 = \boxed{0.000480\ m^3}$$

or

$$X\ m^3 = 480\ cm^3 \left(\frac{1\ m^3}{1000000\ cm^3}\right) = \boxed{4.80 \times 10^{-4}\ m^3}$$

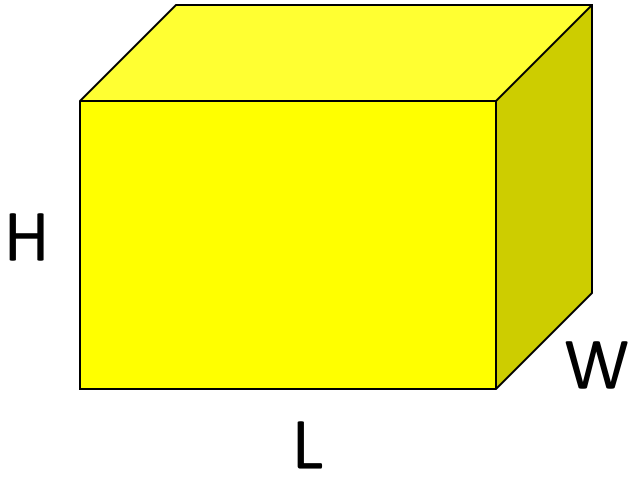
Convert to m^3...

Measured dimensions of a rectangular solid:

Length = 15.2 cm → 0.152 m

Width = 3.7 cm → 0.037 m

Height = 8.6 cm → 0.086 m



Find volume of solid.

$$V = L \cdot W \cdot H$$

$$= (0.152\ m)(0.037\ m)(0.086\ m)$$

$$= 0.000480\ m^3$$

By what factor do mm and cm differ?

10

1 cm = 10 mm

By what factor do mm^2 and cm^2 differ?

100

$(1\ cm)^2 = (10\ mm)^2$

By what factor do mm^3 and cm^3 differ?

1,000

$(1\ cm)^3 = (10\ mm)^3$