Chemistry & STEAM Fundamentals II

Density

An Objects' Relationship of its Mass & Volume

Dr. Ron Rusay

Density

[*http://www.density.com/what.htm*](http://www.density.com/what.htm)

Density = Mass / Volume [g/mL or g/cm^3; g/L; kg/m^3]

mass (m)

$$d = \frac{m}{V} = \frac{156\ \text{g}}{20.0\ \text{cm}^3} = 7.80\ \text{g/cm}^3$$

volume (V)

density (d)

Archimedes 250 B.C.E. Does iron float?.... The RMS Titanic?

Density

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BBC: Secrets of Archimedes
https://www.youtube.com/watch?v=ajQCwTrd5ew

NOVA: Why Do Ships Sink?
https://www.youtube.com/watch?v=n_xDZjrZ6zs

What's below the tip of the iceberg?
https://www.youtube.com/watch?v=-PPGe7MU6ME

Density

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Very Dense Astronomical Objects: White Dwarfs

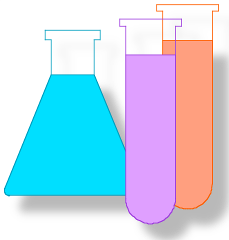
http://antwrp.gsfc.nasa.gov/apod/ap961203.html

$D = 1 \times 10^{9}\ kg/m^3 = 1 \times 10^{3}\ kg/cm^3$

$= 1 \times 10^{6}\ g/cm^3$

A White Dwarf's mass is comparable to our Sun's, but its volume is about a million times smaller; the average density is ~1,000,000 times greater than the Sun's 1.4 kg/m^3

Our Sun will eventually become a white dwarf "butterfly"….. but not for ~5 billion years.

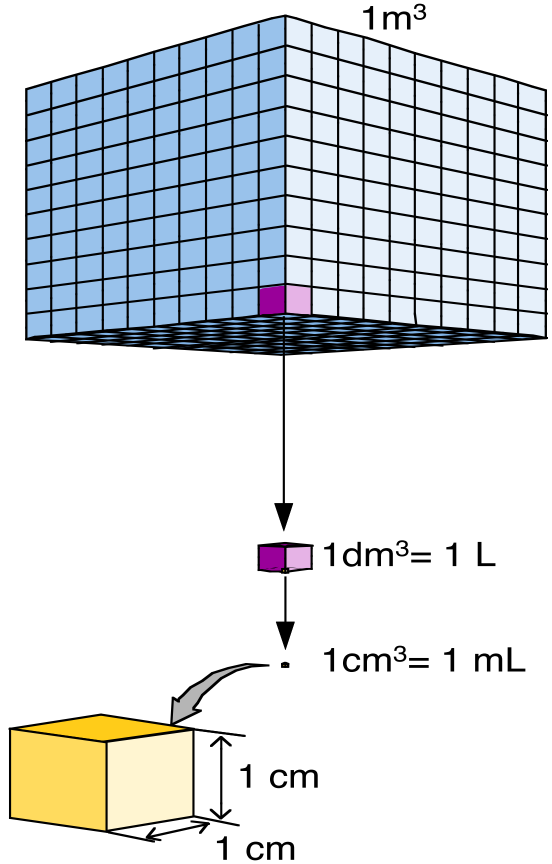


Calculate the density [D(ρ) = ? g/cm^3] of a white dwarf.
A white dwarf volume of 1 m^3 has as a mass of 1.0 x 10^9 kg.

(1 kg = 1000g; 1 m^3 = 1 x 10^6 cm^3)

D(ρ) = ? g/cm^3

1.0 x 10^9 kg / 1 m^3



Conversion Factors can always be looked up. They are found in many references. Selection of which to use determines how to do a calculation.

Dimensional Analysis

Conversion/Unit Factor Calculations

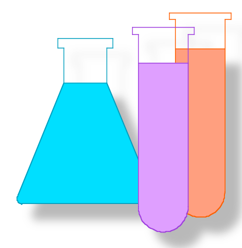
- *Using exact numbers / "scale factors" UNITS*
- *A Bookkeeping Method: Example*

Calculate the density [D(ρ) = ? g/cm^3] of a white dwarf, 1.0 x 10^9 kg / 1 m^3

- (**1 kg = 1000g; 1 m^3 = 1 x 10 ^{6} cm^3; 1 Ton (T) = 1000kg**)

kg	m^3	g
1 m^3	cm^3	kg

= ? g / ? cm^3



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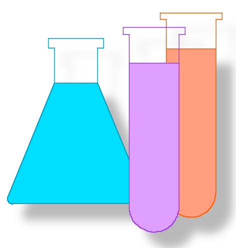
1.0 x 10^9 kg	1 m^3	1,000 g	=	1,000,000 ? g
1 m^3	1.000 x 10^6 cm^3	1 kg		1 ? cm^3



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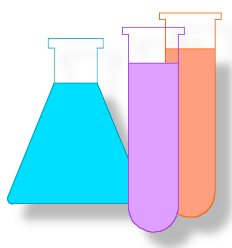
- (**1 kg = 1000g; 1 m^3 = 1 x 10^6 cm^3; 1 Ton (T) = 1000kg**)

kg	*m^3*	*T*	= ______	*? T*
m^3	*cm^3*	*kg*		*? cm^3*



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Conversion/Unit Factor Calculations

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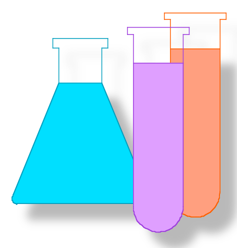
- *A Bookkeeping Method: Example*

Calculate the density [D(ρ) = ? T/cm^3] of a white dwarf, 1.0×10^9 kg / 1 m^3

- (**1 kg = 1000g; 1 m^3 = 1 x 10 ^{6} cm^3; 1 Ton (T) = 1000kg**)

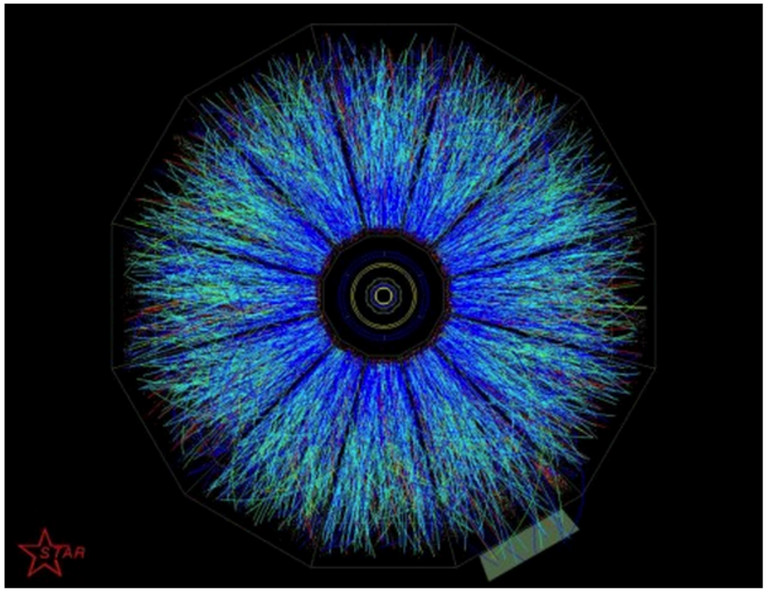
1.0×10^9 kg	1 m^3	1 T	=	1	? T
1 m^3	1.000×10^6 cm^3	1,000 kg		1	? cm^3



Density

Density = Mass / Volume

[g/mL or g/cm^3 or kg/L]; [Also for other objects: g/L or mg/cm^3; kg/m^3]



Known as the quark-gluon plasma, this amazing exotic substance can exist only at incredibly high temperatures or pressures, and it consists almost entirely of free quarks and gluons; it is possible that the whole universe was filled only with this substance in the immediate aftermath of the Big Bang.

"Besides black holes, there's nothing denser than what we're creating," said David Evans, a team leader for the Large Hadron Collider's ALICE detector, which helped observe the quark-gluon plasma shown. "If you had a cubic centimeter of this stuff, it would weigh 40 billion tons."

http://www.zmescience.com/science/physics/quark-gluon-plasma-lhc-26052011/#ixzz3foandtPt

How does quark-gluon plasma's claimed density compare to a white dwarf?

Density

Density = Mass / Volume

[g/mL or g/cm^3 or kg/L]; [Also for other objects: g/L or mg/cm^3; kg/m^3]

How does quark-gluon plasma's claimed density compare to a white dwarf?

"If you had a cubic centimeter of this stuff, it would weigh 40 billion tons."

40 T / 1cm^3 ÷ 1 T /1cm^3 = *40 times larger*

Dimensional Analysis

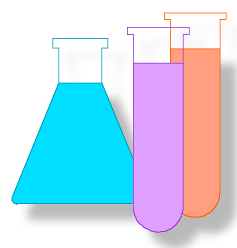
Conversion/Unit Factor Calculations

- *Calculate the density of 1 teaspoon (tsp) of an astronomical object that is claimed to weigh 3 metric tons (T).*

3 T /1 tsp → ? T/cm³ → ? kg/cm³ → ? g/cm³

- *(1 tsp = 4.9289 mL; 1 T = 1,000 kg; 1 kg = 1,000 g; 1 mL = 1 cm³)*

$$\frac{T}{tsp} \times \frac{tsp}{mL} \times \frac{mL}{cm^3} = \frac{?\,T}{cm^3}$$



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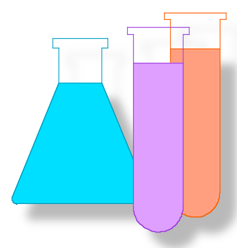
- *(1 tsp = 4.9289 mL; 1 T = 1,000 kg; 1 kg = 1,000 g; 1 mL = 1 cm³)*

3 T	1 tsp	1 mL	=	6 x 10^{-1} ? T
1 tsp	4.9289 mL	1 cm^3		cm^3



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Conversion/Unit Factor Calculations

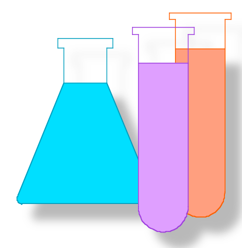
- Calculate the density of 1 teaspoon (tsp) of an astronomical object that is claimed to weigh 3 metric tons (T).

$3\ T / 1\ tsp \rightarrow ?\ T/cm^3 \rightarrow ?\ kg/cm^3 \rightarrow ?\ g/cm^3$

- (1 tsp = 4.9289 mL; 1 T = 1,000 kg; 1 kg = 1,000 g; 1 mL = 1 cm^3)

$$\frac{3\ T}{1\ tsp} \left| \frac{1\ tsp}{4.9289\ mL} \right| \frac{1\ mL}{1\ cm^3} \left| \frac{1{,}000\ kg}{1\ T} \right. = \frac{?\ kg}{cm^3}$$

6×10^2



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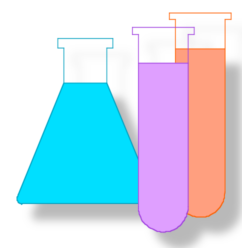
3 T	1 tsp	1 mL	1,000 kg	1,000 g	=	6×10^5 ? g
1 tsp	4.9289 mL	1 cm^3	1 T	1 kg		cm^3



Density: *Ultralight microlattices*

Density = Mass / Volume [g/mL or g/cm^3; g/L; kg/m^3]

T. A. Schaedler et al. Science 2011;334:962-965

http://www.gizmag.com/ultralight-micro-lattice-material/20537/

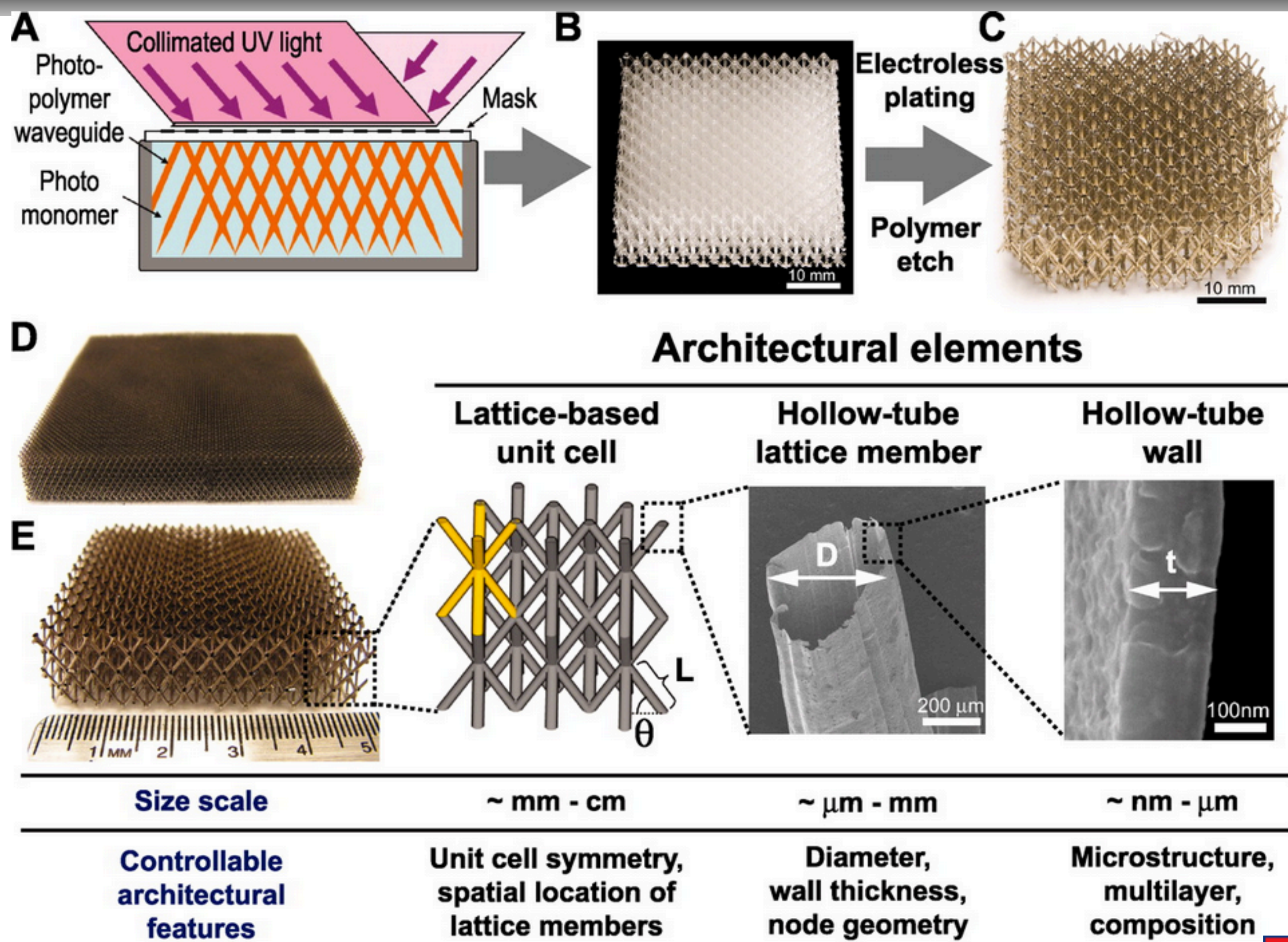
0.9 mg/cm^3 (air = 1.2 mg/cm^3)

Published by AAAS

Engineering Ultralight Microlattices

Density = Mass / Volume [g/mL or g/cm^3; g/L; kg/m^3]

T. A. Schaedler et al. Science 2011;334:962-965



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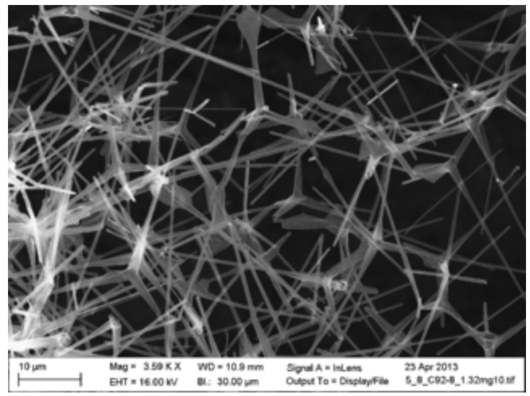

- *Aerographite is a synthetic foam consisting of a porous interconnected network of carbon nanotubes. It was first reported by researchers at the University of Kiel and the Technical University of Hamburg in Germany in a scientific journal in June 2012. It's density is:*
- *D = 0.18 mg/cm^3*

Density

Density = Mass / Volume [g/mL or g/cm^3; g/L; kg/m^3]

https://www.youtube.com/watch?v=3bIXUBXj070

The graphene aerogel can be supported by blades of grass

0.16 mg/cm^3

Chao Gao et. al., Zhejiang University, Department of Polymer Science and Engineering

Nature 494, 404 (28 February 2013)

doi:10.1038/494404a

QUESTION

A metal sample is hammered into a rectangular sheet with an area of 31.2 ft^2 and an average thickness of 2.30×10^{-6} cm. If the mass of this sample is 0.4767 g, predict the identity of the metal.

The density of the metal is shown in parenthesis.
Useful information: 1 ft = 12 in; 1 in = 2.54 cm

A) Aluminum (2.70 g/cm^3)

B) Copper (8.95 g/cm^3)

C) Gold (19.3 g/cm^3)

D) Zinc (7.15 g/cm^3)

Answer

A metal sample is hammered into a rectangular sheet with an area of 31.2 ft^2 and an average thickness of 2.30×10^{-6} cm. If the mass of this sample is 0.4767 g, predict the identity of the metal.

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ft^2	in^2	cm^2	cm	=	?
	ft^2	in^2			

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$$31.2\ ft^2 \times \frac{12 \times 12\ in^2}{1\ ft^2} \times \frac{2.54 \times 2.54\ cm^2}{1\ in^2} \times 2.30 \times 10^{-6}\ cm =$$

0.066667222 cm^3

$6.67 \times 10^{-2}\ cm^3$

$0.4767\ g / 6.67 \times 10^{-2}\ cm^3 =$

$7.15\ g/cm^3$

*Densities of Various Common Substances**

Densities of Various Common Substances* at 20°C

Substance	Physical State	Density (g/cm^3)
Oxygen	Gas	0.00133
Hydrogen	Gas	0.000084
Ethanol	Liquid	0.789
Benzene	Liquid	0.880
Water	Liquid	0.9982
Magnesium	Solid	1.74
Salt (sodium chloride)	Solid	2.16
Aluminum	Solid	2.70
Iron	Solid	7.87
Copper	Solid	8.96
Silver	Solid	10.5
Lead	Solid	11.34
Mercury	Liquid	13.6
Gold	Solid	19.32

*At 1 atmosphere pressure

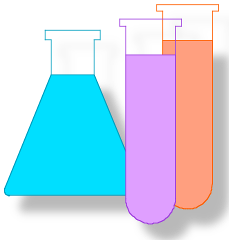
Density

Density = Mass / Volume [g/mL or g/cm^3; g/L]

Mass = Density x Volume

- *How many grams of air are there in PS 221?*
- *The room has dimensions of ~ 3.5 m x 11 m x 10. m.*
- $D_{air} = 1.22 \times 10^{-3}$ g/cm^3 (1.22 g/L)
- 1m^3 = 100 cm x 100 cm x 100 cm;
- 1000 cm^3 = 1 L; 1 mL = 1 cm^3

A. 1.22×10^3 g
B. 385,000,000 g
C. 3.85×10^6 g
D. 47,000,000 g
E. 4.70×10^8 g



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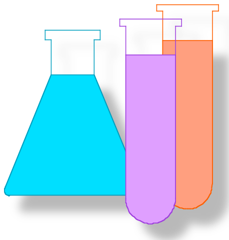

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Conversion/Unit Factor Calculations

- How many grams of air are there in PS 221?
- The room has dimensions of ~ 3.50 m x 11.0 m x 10.0 m. = 385 m^3
- D_{air} = 1.22 x 10^{-3} g/cm^3 (1.22 g/L)
- 1m^3 = 100 cm x 100 cm x 100 cm;
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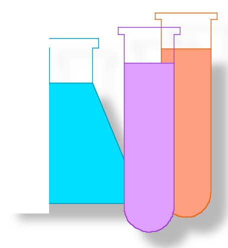
385 m^3	cm^3	1.22 g	=	?
	m^3	1 cm^3		



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- *How many grams of air are there in PS 221?*
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- $D_{air} = 1.22 \times 10^{-3}$ g/cm^3 (1.22 g/L)
- 1m^3 = 100 cm x 100 cm x 100 cm;
- 1000 cm^3 = 1 L; 1 mL = 1 cm^3

$$385\ m^3 \left| \frac{1 \times 10^6\ cm^3}{1\ m^3} \right| \frac{1.22\ g}{1\ cm^3} = \begin{array}{l} 470. \times 10^{6}\ g \\ 4.70 \times 10^{8}\ g \end{array}$$