show Cosmic Voyage + Veritasium World's Roundest Object

Deb Rosenthal Fall 2018 (P.3)

Methods and Tools of Physics

Order of Magnitude Estimation: Estimation made to the nearest power of ten.

Give an order of magnitude estimate for each of the following quantities.

1. The number of students enrolled at SEHS (1500) — 10^3
2. The number of teachers at SEHS (≈70) — 10^1
3. The number of seconds in this period (60×72) = 4320 — 10^3
4. The height of the door in meters — 10^0
5. The thickness of the door in meters — 10^{-2}
6. The thickness of a piece of paper in meters (cm) — 10^{-4}

Ranges of magnitudes that occur in the universe:

Sizes: 10^{-15} m (subnuclear particles) to 10^{+25} m (extent of the visible universe)

Masses: 10^{-30} kg (electron mass) to 10^{+50} kg (mass of the universe)

Times: 10^{-23} s (passage of light across a nucleus) to 10^{+18} s (the age of the universe)

Size of an atom: 10^{-10} m - angstrom Å

Size of a proton: 10^{-15} m 100,000x smaller than atom

Significant Figures, Decimal Places, and Scientific Notation

Decimal places – the number of digits after the decimal point

Significant figures (digits) –the digits that are known with certainty plus one digit whose value has been estimated in a measured value.

Measurement	Decimal Places	Significant Figures	Scientific Notation
4003 m	Ø	4	4.003×10^3 m
160 N	Ø	2	1.6×10^2 N
160. N	Ø	3	1.60×10^2 N
30.00 kg	2	4	3.000×10^1 Kg
0.00610 m	5	3	6.10×10^{-3} m

_ . _ _ 610 m

Rules for determining significant figures:

1. Nonzero digits in a measurement are always significant.
2. Zeros that appear *before* a nonzero digit are *NOT* significant.

   Ex – 0.002 m (1 significant figure) and 0.13 g (2 s.f.).
3. Zeros that appear *between* nonzero digits are significant.

   Ex – 0.705 kg (3 s.f.) and 2006 km (4 s.f.).
4. Zeros that appear *after* a nonzero digit are significant *only* if:

   (a) followed by a decimal point

   Ex - 40 s (1 s.f.) and 20. m (2 s.f.).

   (b) they appear to the right of the decimal point.

   Ex – 37.0 cm (3 s.f.) and 40.00 m (4 s.f.).

Calculations with Significant Figures

Addition and Subtraction Rule

When adding or subtracting measured values, the operation is performed and the answer is rounded to the same **decimal place** as the value with the **fewest decimal places.**

Multiplication and Division Rule

When multiplying or dividing measured values, the operation is performed and the answer is rounded to the same number of **significant figures** as the value having the **fewest number of significant figures.**

Perform the following calculations and answer to the correct number of sig figs:

a)
11.44 m
5.00 m
0.11 m
+ 13.2 m

29.8 m

b) Add 2.34 m, 35.7 m and 24 m

62 m

c) (0.304 cm) (73.84168 cm) 3sf

22.4 cm^2

d) 0.1700 g ÷ 8.50 L 3s.f.

2.00×10^{-2} g/L

Fundamental and Derived Units

The SI (International System) system of units defines seven fundamental units from which all other units are derived.

For example:

The **meter** is the length of the path traveled by light in vacuum during a time interval of 1/299 792 458 of a second.

The **second** is the duration of 9 192 631 770 periods of the radiation corresponding to the transition between the two hyperfine levels of the ground state of the cesium 133 atom.

Fundamental Units

Quantity	Units	Symbol
Length	meter	m
Mass	Kilogram	Kg
Time	second	s
Electric current	ampere	A
Temperature	Kelvin	K
Amount	mole	mol
Luminous intensity	candela	cd

Derived Units

New (derived) units can be named by combining the fundamental units.

a) What is the derived unit for *mass per length*? Kg/m $\frac{Kg}{m}$

b) What is the derived unit for *electric current times time*? A·s (coulomb)

c) What is the derived unit for *mass times length per time*? Kg $\frac{m}{s}$ (momentum)

Note: Sometimes a derived unit will have a new name.

For example, $Kg\frac{m}{s^2} = 1N$

Metric Prefixes and

Prefixes for Powers of Ten

PREFIX	SYMBOL	NOTATION
tera	T	10^{12}
giga	G	10^{9}
mega	M	10^{6}
kilo	k	10^{3}
deci	d	10^{-1}
centi	c	10^{-2}
milli	m	10^{-3}
micro	µ	10^{-6}
nano	n	10^{-9}
pico	p	10^{-12}

1. Convert 45.20 centimeters into meters.

$45.20\,\text{cm} \times \frac{1\,\text{m}}{100\,\text{cm}} = 4.520 \times 10^{-1}\,\text{m}$

Factor-Label Method for Converting Units

a) Write factors so units cancel leaving desired units.

b) Write "1" next to each prefixed unit.

c) Write the power of 10 (i.e.- the exponent) with each base unit.

2. Convert 1.9 A into microamps. Okay if not completed

$1.9\,\text{A} \times \frac{1\,\mu\text{A}}{1 \times 10^{-6}\,\text{A}} = 1.9 \times 10^{6}\,\mu\text{A}$

3. Convert 0.0340 pm into kilometers.

$0.0340\,\text{pm} \times \frac{1 \times 10^{-12}\,\text{m}}{1\,\text{pm}} \times \frac{1\,\text{Km}}{1 \times 10^{3}\,\text{m}} = 3.40 \times 10^{-17}\,\text{Km}$

4. Convert 12.8 cm^2 into m^2.

$12.8\,\text{cm}^2 \times \left(\frac{1 \times 10^{-2}\,\text{m}}{\text{cm}}\right)^2 = 1.28 \times 10^{-3}\,\text{m}^2$

5. Convert 4700 kg/m^3 into g/cm^3

$4700\,\frac{\text{Kg}}{\text{m}^3} \times \frac{1 \times 10^{-2}\,\text{m}}{\text{cm}} \times \frac{1 \times 10^{-2}\,\text{m}}{\text{cm}} \times \frac{1 \times 10^{-2}\,\text{m}}{\text{cm}} \times \frac{1000\,\text{g}}{\text{Kg}} = 4.7\,\frac{\text{g}}{\text{cm}^3}$

6. Convert 55 mph into m/s. (1.0 mile ≈ 1.6 km)

$\frac{55\,\text{miles}}{\text{hr}} \times \frac{1.6\,\text{Km}}{\text{mile}} \times \frac{1 \times 10^{3}\,\text{m}}{\text{Km}} \times \frac{1\,\text{hr}}{3600\,\text{s}} = 24\,\frac{\text{m}}{\text{s}}$

or $2.4 \times 10^{1}\,\text{m/s}$

Extra practice

7. Convert 700 seconds into nanoseconds.

7×10^{11} ns

8. Convert 2.40 gigabytes into bytes.

2.40×10^{9} bytes

9. Convert 10.25 Mℓ into mℓ.

1.025×10^{10} mL

10. Convert 45.0 m^3 into mm^3.

4.50×10^{10} mm^3

$$\left(\frac{10^3\,mm}{1\,m}\right)^3 \times 45.0\,m^3$$

11. Convert 92.3 kg/cm^3 into g/m^3.

$9.23 \times 10^{10}\ \frac{g}{m^3}$

12. Convert 30. m/s in to mph.

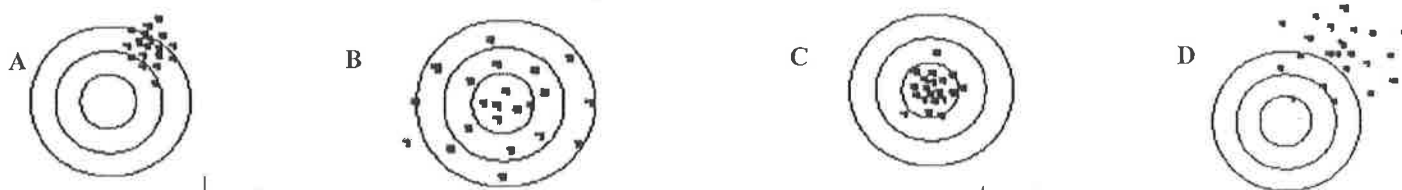
68 mph

Accuracy and Precision

Accuracy: An indication of how close a measurement is to the accepted value (a measure of correctness)

Precision: An indication of the agreement among a number of measurements made in the same way (a measure of exactness) how close measurements are to each other

Rate the following groupings of shots on their accuracy and precision:



A: precise but not accurate

B: not precise or accurate (?)

C: accurate + precise

D: not accurate not precise (?)

Systematic Error: An error associated with a particular instrument or experimental technique that causes the measured value to be off by a consistent, predictable amount each time.

Random Uncertainty: An uncertainty produced by unknown and unpredictable variations in the experimental situation whereby the recorded measurement has an equal probability of being above or below the true value.

1) Which target(s) above represents measurements made with significant systematic error? A + D (not accurate)
2) Which target(s) above represent measurements made with significant random uncertainty? B + D
3) Which type of uncertainty affects the accuracy of results? systematic error
4) Which type of uncertainty affects the precision of results? random uncertainty
5) Which type of uncertainty can be eliminated from an experiment? systematic error
6) Which type of uncertainty can be reduced in an experiment but never eliminated? random uncertainty
7) State a general method for reducing random uncertainty. repeated trials
8) Repeated measurements can make your answer more precise but not more accurate
9) An accurate experiment has low systematic error
10) A precise experiment has low random uncertainty