HIGH SCHOOL CHEMISTRY

CHAPTER 1

Set 2: Measurement

Free Preview Sampler

Measurement: units, scientific notation, significant figures and temperature

Free preview of the full Measurement set

7	1	100%	2
products in the set	full lesson, free	original content	levels: Regular + Honors

- A full lesson on significant figures, free
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For high school chemistry, Regular and Honors. Chapter 1: Matter, Measurement, and Problem Solving.
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WELCOME

Try it before you buy it

This free sampler shows **real content** from the Measurement study set for high school chemistry. Read a full lesson, try a few practice questions and exam traps, and flip through pages from every product. If it helps, the full set takes you the rest of the way.

7	1	100%	2
separate products	full lesson free inside	original content	levels: Regular + marked Honors

Measurement is where easy points disappear

- ✓ correct math marked wrong because the answer has **too many significant figures**;
- ✓ a cylinder read at the **top** of the meniscus instead of the bottom;
- ✓ **mL** and **cm³** treated as different things, or **m** and **M** mixed up;
- ✓ °F converted to °C in the **wrong order**;
- ✓ the **kilogram** forgotten as the SI base unit of mass.

The full set covers every one of these, with plain explanations, diagrams and lots of practice.

What the colored badges mean

Badge	What it means	Badge	What it means
★ HONORS	**Honors only.** Regular students can skip it.	TIP	A shortcut or memory hook.
KEY IDEA	The one or two sentences to know first.	EXAMPLE	A worked example, every step shown.
EXAM TRAP	A mistake that costs points on tests.	DEFINITION	A term to know word for word.

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The Full Measurement Set

Each product works on its own, so you can buy just what you need. Together they cover the Measurement section of high school chemistry, Regular and Honors. Dimensional analysis and density calculations are in the companion **Problem Solving** set.

#	Product	What you get	Pages
01	**Complete Study Notes**	The full course: 9 lessons, original diagrams, worked examples with every step, quick checks with answers.	47
02	**Quick Revision Sheets**	Short notes: simple tables, flowcharts, formula boxes, memory hooks, and a one-page cheat sheet.	24
03	**Exam Traps and Mistakes**	The mistakes that cost points, shown wrong vs. right, with the fix for each one.	46
04	**Practice Question Bank**	Easy to challenge questions in every format, instrument-reading practice, and full worked solutions.	77
05	**Practice Tests and Answer Keys**	Quick quizzes and full unit tests with answer keys and point-by-point scoring guides.	49
06	**Glossary and Flashcards**	Every term in plain English, plus printable cut-out flashcards.	42
07	**Lab Skills for Tests**	Lab questions from tests: safety, readings, data and errors.	25

KEY IDEA | Who it is for

High school chemistry students in **Regular** or **Honors** courses, parents helping at home, and tutors who want ready-made, clearly explained material.

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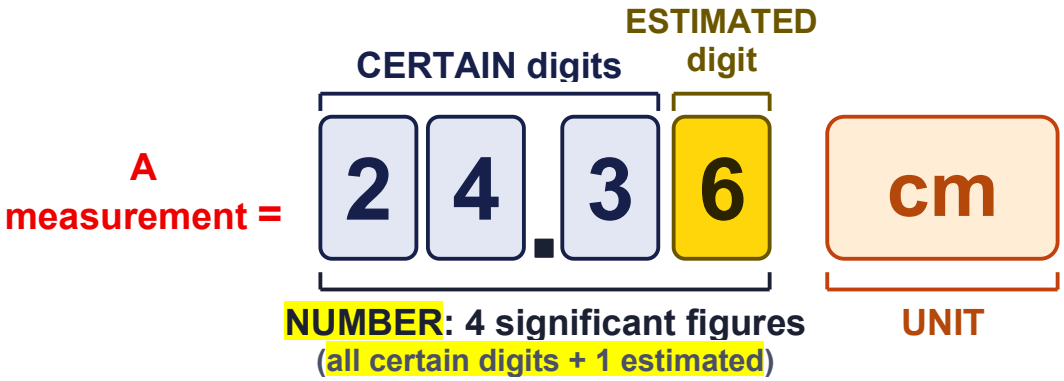
SNEAK PEEK

See what a measurement really says

Every page explains with pictures first, then numbers. Here is the big idea of the whole topic, and one of the worked examples that uses it.



Every measurement is certain digits, one estimated digit, and a unit (Lesson 1). Every measurement has a number and a unit. The number holds every digit you are sure of plus ONE estimated digit; together these are the significant figures.

WORKED EXAMPLE | Significant figures in a two-step calculation

Read

A student measures a liquid level of **25.48 mL** before and **24.3 mL** after pouring some out, and the poured liquid has a mass of **2.15 g**. **Find:** the mass per milliliter, to the correct significant figures.

Plan

Subtract first (decimal-place rule), then divide (sig-fig rule). Keep extra digits until the very end.

Solve

$25.48\ \text{mL} - 24.3\ \text{mL} = 1.18\ \text{mL}$ *only 1 decimal place is trustworthy, so this is really 1.2 (2 s.f.)*

$\frac{2.15\ \text{g}}{1.18\ \text{mL}} = 1.8220\ldots\ \text{g/mL}$ *divide using the unrounded 1.18*

$= \mathbf{1.8\ g/mL}$ *2 s.f., because the volume has only 2*

Check

The weakest number decides. 24.3 mL is known only to the tenths place, which cut the volume to 2 significant figures, so the answer gets 2.

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LESSON 1 What Makes a Good Measurement

LEARNING GOALS | By the end of this lesson you can

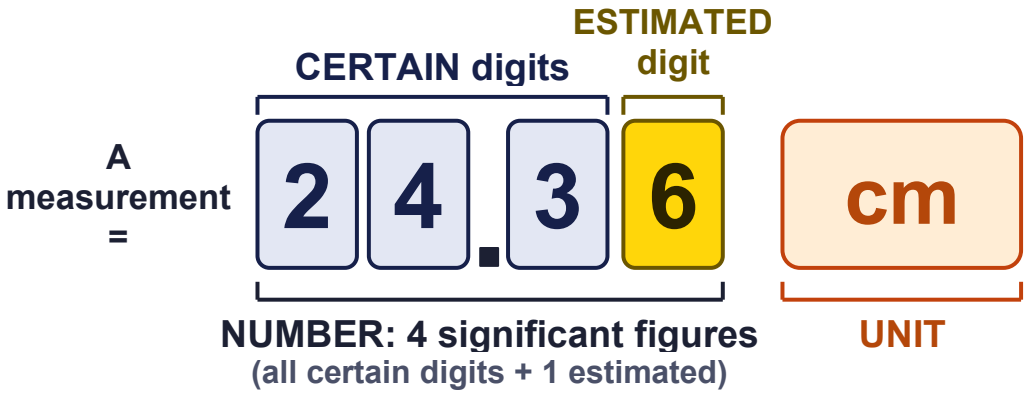
- Tell a quantitative observation from a qualitative one.
- Name the SI base units and their symbols.
- Explain the difference between mass and weight.
- Use everyday lab units such as mL, cm^3 and °C.

KEY IDEA

A measurement always has **a number and a unit**. The number contains **every digit you are sure of plus one estimated digit**, so it tells the reader both the size of the quantity and how carefully it was measured.

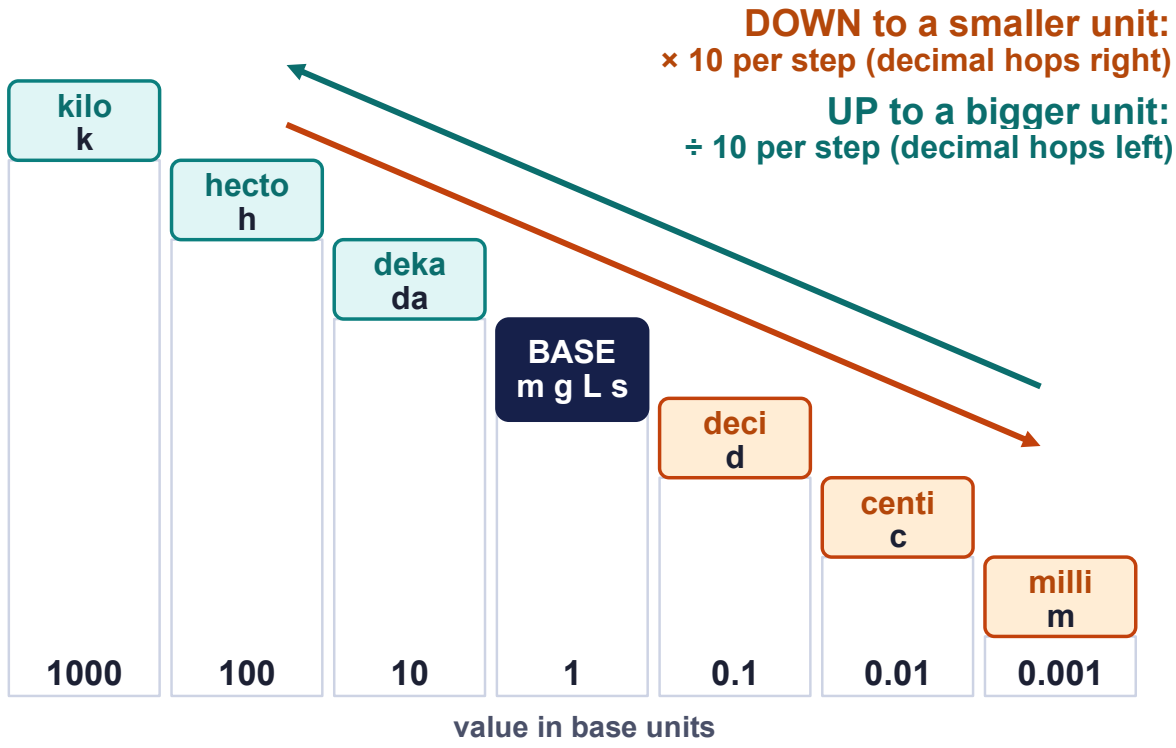
1.1 Number + unit

Suppose a recipe card says "add 2 of flour". Two cups? Two grams? Two pounds? Without a unit the number is useless. **In science the unit is never optional.**



The anatomy of a measurement. Every measurement has a number and a unit. The number holds every digit you are sure of plus ONE estimated digit; together these are the significant figures.

*The prefixes in **bold** are the ones that appear most often on tests. Hecto and deka are rare in real chemistry but fill the gaps on the staircase below.*

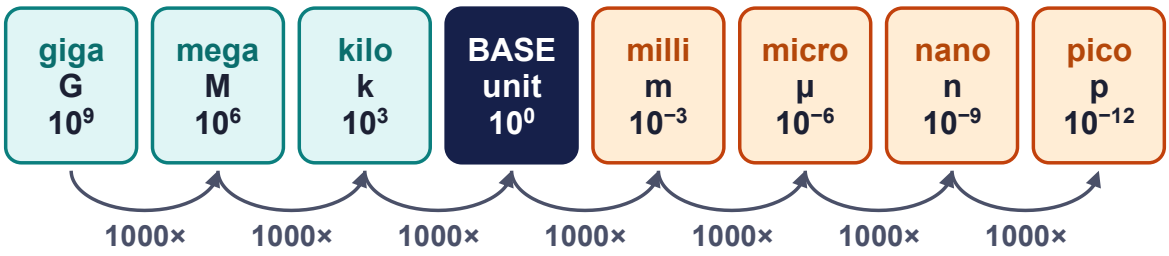


The metric staircase, from kilo down to milli. Each step is a factor of 10. Going down to a smaller unit, the number gets bigger: 2.5 km = 2500 m = 250 000 **cm**. Going up to a larger unit, the number gets smaller.

MEMORY TRICK | Climb the staircase in order

Kayla **H**as **D**one **B**ig **D**ance **C**lub **M**oves: **k**ilo, **h**ecto, **d**eka, **B**ase, **d**eci, **c**enti, **m**illi. Count the steps between two prefixes, and move the decimal point that many places.

The big jumps: each neighbor is 1000 times bigger or smaller



Beyond kilo and milli the common prefixes jump by 1000.

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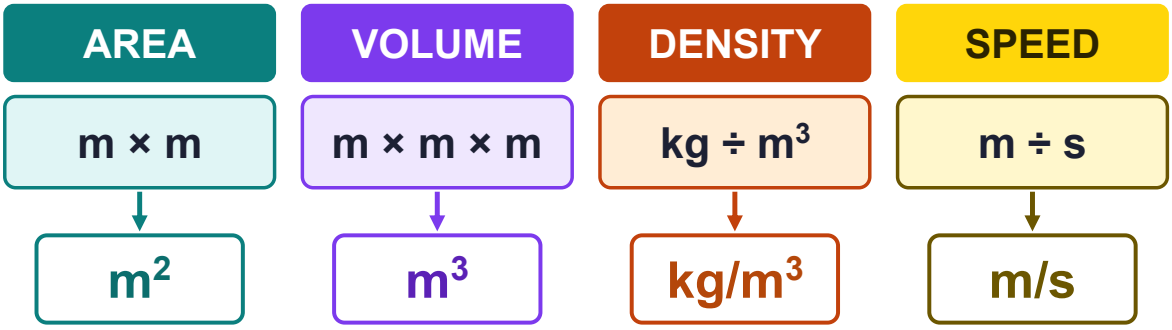
2.3 Derived units

DEFINITION | Derived unit

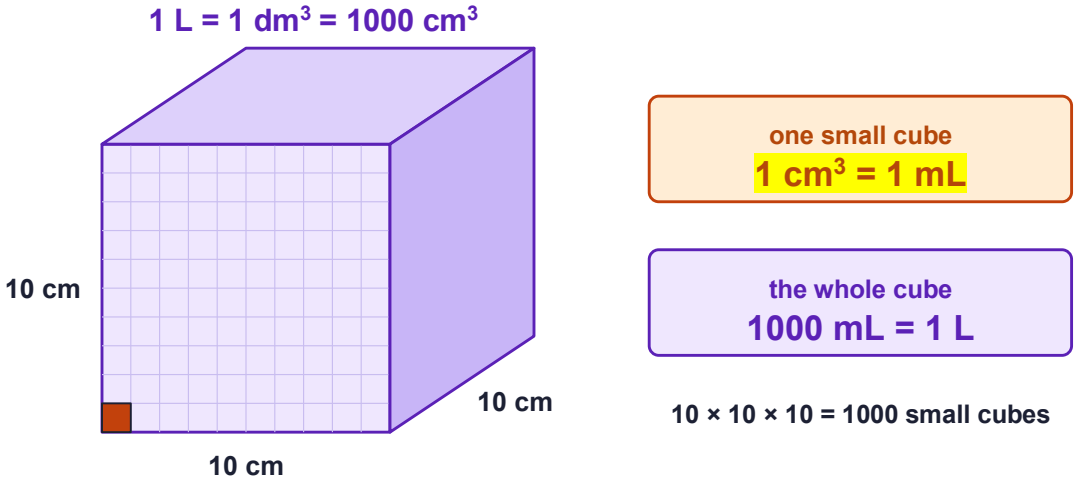
A unit made by multiplying or dividing base units, such as m^2 for area, m^3 for volume, kg/m^3 for density and m/s for speed.



Derived units are built from base units. A derived unit is built by multiplying or dividing base units. In the lab we usually use the smaller versions: cm^2, cm^3 (= mL), g/cm^3 and g/mL.

Volume

Volume is the space an object takes up. Its SI unit, the cubic meter, is huge (a cube 1 m on each side), so chemists use smaller units: the **liter (L)**, the **milliliter (mL)** and the **cubic centimeter (cm^3)**.



Why 1 mL is exactly the same as 1 cm^3. A cube 10 cm on each side holds exactly 1 liter. Each 1 cm cube inside it holds 1 mL, which is why **"cc", cm^3 and mL all name the same volume.**

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LESSON 4 Reading Lab Instruments

LEARNING GOALS | By the end of this lesson you can

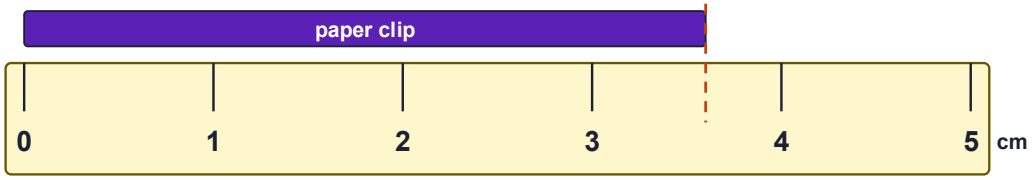
- Read a ruler, graduated cylinder and thermometer to one estimated digit.
- Read a meniscus at eye level and a buret from the top down.
- Record balance readings and find a mass by difference.

KEY IDEA

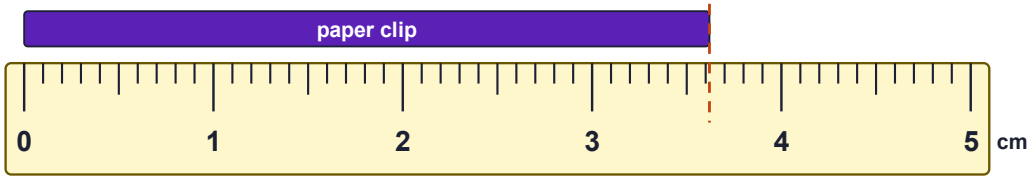
Record **every digit the scale lets you be sure of, plus one estimated digit**. For a scale with markings, estimate to **one-tenth of the smallest division**. For a digital display, record **every digit shown**.

No measurement is perfect. The last digit you write is always a careful estimate, and how many digits you can write depends on the instrument, not on how hard you try. That is why the same object can give "3.6 cm" with one ruler and "3.62 cm" with another.

4.1 Rulers: the same clip, two rulers



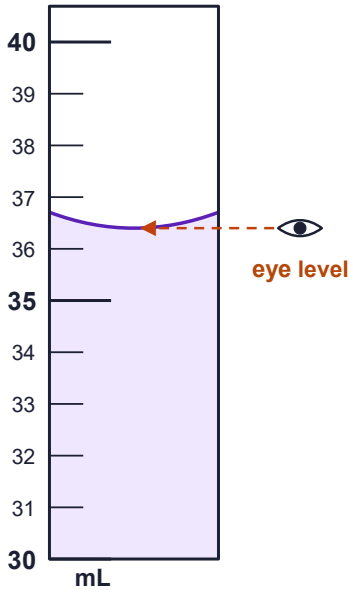
Ruler A, marked only in whole centimeters: 3.6 cm. This ruler is marked only every 1 cm, so we estimate to 0.1 cm: reading 3.6 cm. Same clip, fewer certain digits.



Ruler B, marked in millimeters: 3.62 cm. The smallest marks are 0.1 cm (millimeters), so we estimate to 0.01 cm. The clip ends past 3.6 and about one-fifth of the way to 3.7: reading 3.62 cm.

Ruler A lets you be sure of the 3; the 6 is the estimate. Ruler B lets you be sure of 3.6; the 2 is the estimate. **Ruler B gives one more significant figure** because its markings are ten times finer.

4.2 Graduated cylinders and the meniscus



Read the bottom of the meniscus at eye level: 36.4 mL. This cylinder is marked every 1 mL, so we estimate to the nearest 0.1 mL. The bottom of the meniscus sits between 36 and 37, a little less than halfway: reading 36.4 mL.

DEFINITION | Meniscus

The curved surface of a liquid in a narrow tube. Water curves **down** in the middle, so you read the **bottom** of the curve.

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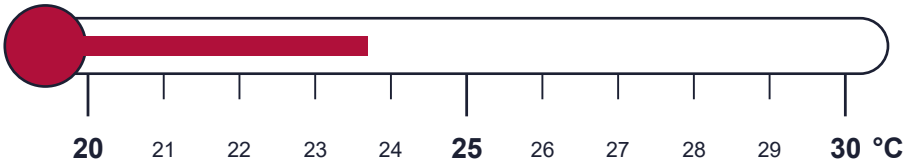
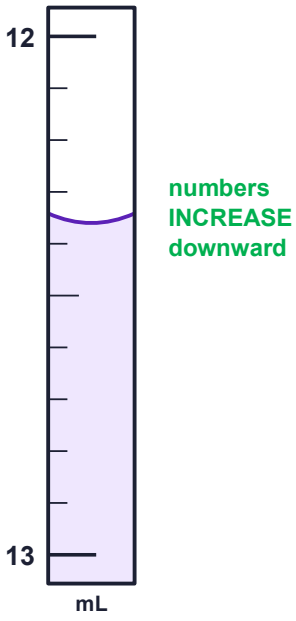
LAB SKILL | Reading any glass scale

- Put the container on a flat bench. Do not hold it up in the air.
- Bend down so your eye is **level** with the liquid surface. Looking from above or below shifts the reading (**parallax error**).
- Work out what one small division is worth: (difference between two labeled lines) ÷ (number of spaces between them).
- Write the certain digits, then estimate one more digit.

4.3 Thermometers, burets and balances



Thermometer marked every 1 °C: 23.7 °C. Marks every 1 °C, so we estimate to 0.1 °C: the liquid stops about seven-tenths of the way from 23 to 24, reading 23.7 °C.



A buret reads from the top down: 12.36 mL. A buret reads from the top down. Marks every 0.1 mL, so we estimate to 0.01 mL: reading 12.36 mL.

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LESSON 6 Significant Figures in Measurements

LEARNING GOALS | By the end of this lesson you can

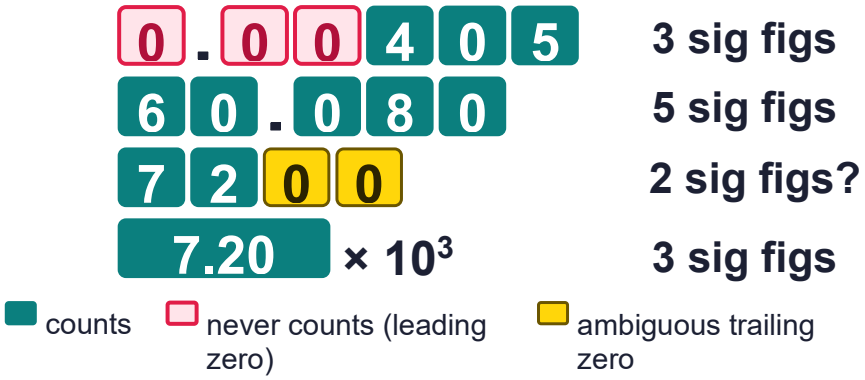
- Count the significant figures in any measured number.
- Recognize exact numbers and explain why they never limit an answer.
- Round a number to a given number of significant figures.

KEY IDEA

The **significant figures** in a measured number are all of its certain digits plus the one estimated digit. **Every nonzero digit counts.** Zeros count only when they are measured digits, not when they just hold the decimal point in place.

6.1 The rules

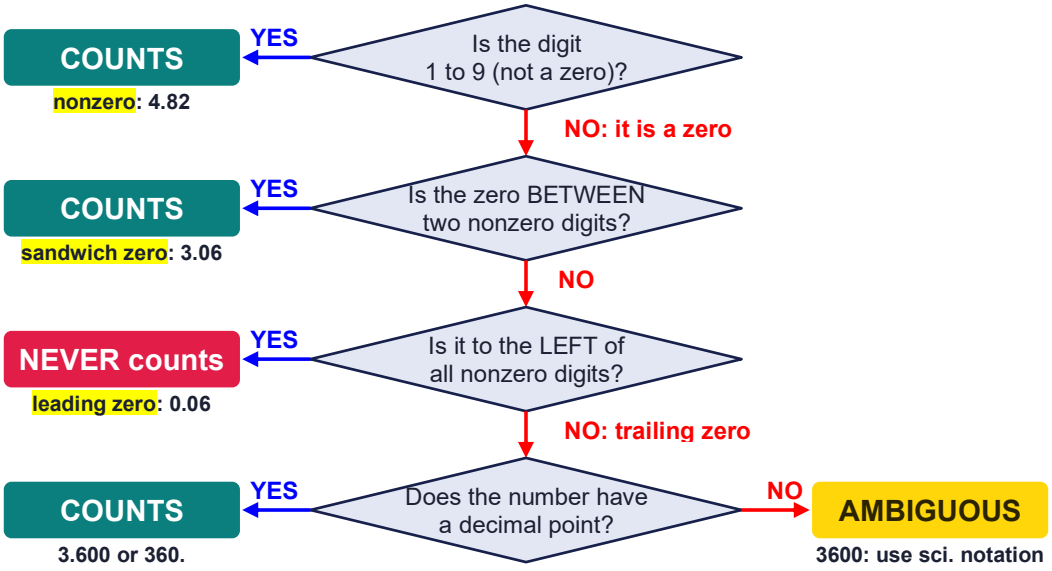
Type of digit	Rule	Example	Number of Sig figs
Nonzero digits (1–9)	Always significant.	4.82	3
Sandwich zeros (between nonzero digits)	Always significant.	3.06, 5002	3, 4
Leading zeros (before the first nonzero digit)	Never significant. They only place the decimal point.	0.0072	2
Trailing zeros, with a decimal point	Significant.	2.50, 360.	3, 3
Trailing zeros, no decimal point	Ambiguous. Use scientific notation to make the meaning clear.	3600	2, 3 or 4?
Scientific notation	Every digit in the coefficient counts; the power of ten does not.	3.60×10^3	3



Which digits count: color-coded. 0.00405: leading zeros only place the decimal point (3 sig figs). 60.080: the sandwiched zeros and the trailing zero after the decimal point all count (5). 7200 with no decimal point is ambiguous; writing 7.20×10^3 shows clearly that there are 3.

MEMORY TRICK | Leaders lie, sandwiches stay, trailers need a point

Leading zeros never count. **Sandwiched** zeros always count. **Trailing** zeros count only if the number shows a decimal point.



Run any zero through this flowchart. Run each zero through the questions from the top. Every nonzero digit counts. A zero counts if it is sandwiched, or if it trails AND the number shows a decimal point.

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6.2 Exact numbers

DEFINITION | Exact number

A number with **no uncertainty**: either **counted** (24 students, 3 trials) or **defined** (1 m = 100 cm, 1 in = 2.54 cm, 1 kg = 1000 g). Exact numbers have unlimited significant figures, so they **never** limit the precision of an answer.

WORKED EXAMPLE | Count the significant figures

Read

How many significant figures in: (a) 0.050 30 g (b) 7008 m (c) 9.200×10^{-4} s (d) 450 cm (e) 12 eggs?

Solve

(a) 0.050 30 → **4** *leading 0.0 not counted; 5, sandwiched 0, 3, trailing 0 after the decimal point*

(b) 7008 → **4** *both zeros are sandwiched*

(c) 9.200×10^{-4} → **4** *count only the coefficient*

(d) 450 → **2 (ambiguous)** *no decimal point; write 4.5×10^2 or 4.50×10^2 to be clear*

(e) 12 eggs → **exact** *counted, so unlimited*

6.3 Rounding

Round 2.4687 to 3 sig figs

2 . 4 6 8 7

keep these 3 decider

8 is 5 or more, so the last kept digit goes up: 2.47

Look only at the first digit you drop. Look only at the first digit you are dropping (the decider). 5 or more: raise the last kept digit by one. Less than 5: leave it alone. Then drop everything after it.

- Decide how many significant figures to keep, and find the **last kept digit**.
- Look at the **next** digit (the decider). If it is **5 or more**, add 1 to the last kept digit. If it is **less than 5**, leave the last kept digit alone.
- Drop the rest. If they are to the left of the decimal point, replace them with zeros (or better, switch to scientific notation).

Number	Round to	Answer	Note
8.0549	3 s.f.	8.05	decider 4: no change
0.026 75	2 s.f.	0.027	decider 7: round up
63 851	2 s.f.	64 000 = 6.4×10^4	zeros are placeholders
9.97	2 s.f.	10.	the decimal point shows the 0 counts
3.4500	2 s.f.	3.5	decider 5: round up

EXAM TRAP | Round once, from the original number

Rounding 2.346 to 2 s.f. gives **2.3** (decider 4). Rounding it in stages, 2.346 → 2.35 → 2.4, gives the wrong answer. Always look back at the original digits.

QUICK CHECK | Try it before you move on

1. How many significant figures: (a) 0.0040; (b) 20.07; (c) 5.10×10^6; (d) 1200; (e) 100.0?
2. Which of these is exact: (a) 1 L = 1000 mL; (b) a measured 1000 mL of water; (c) 6 test tubes?
3. Round 0.004 965 to (a) 3 s.f.; (b) 2 s.f.; (c) 1 s.f.
4. Write 52 000 so that it clearly has 3 significant figures.

Answers: 1) (a) 2; (b) 4; (c) 3; (d) ambiguous (2 to 4); (e) 4. 2) (a) and (c) are exact; (b) is measured. 3) (a) 0.004 97; (b) 0.0050; (c) 0.005. 4) 5.20×10^4.

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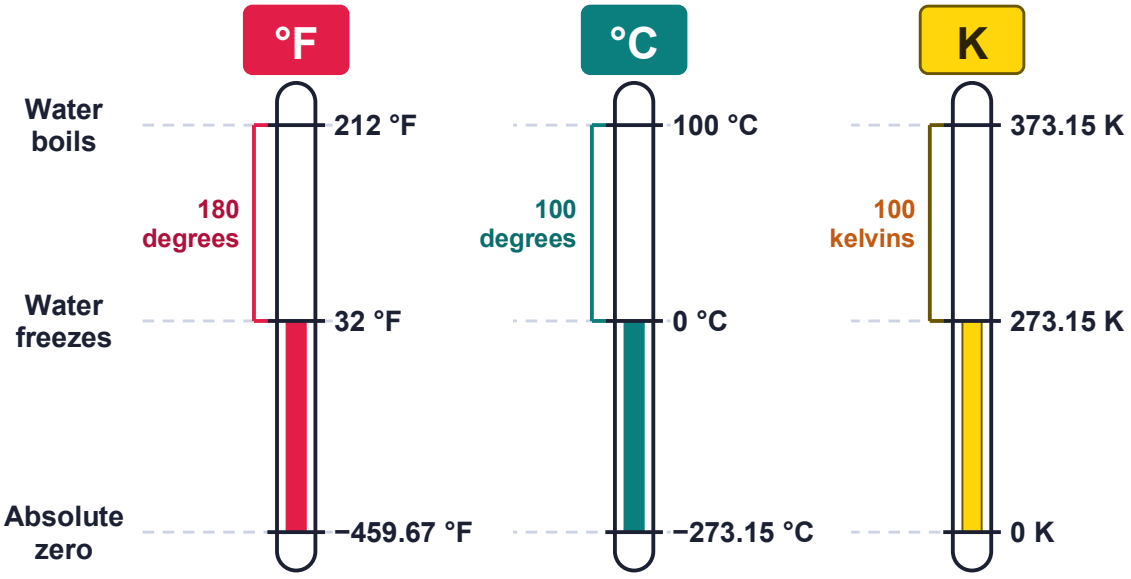
8.1 Three scales



Fahrenheit, Celsius and Kelvin side by side. From freezing to boiling water there are 100 Celsius degrees, 100 kelvins, but 180 Fahrenheit degrees. A kelvin is the same size as a Celsius degree; a Fahrenheit degree is smaller (1.8 of them fit in one Celsius degree). Boiling point at normal air pressure.

	Fahrenheit	Celsius	Kelvin
Water freezes	32 °F	0 °C	273.15 K
Water boils	212 °F	100 °C	373.15 K
Body temperature	about 98.6 °F	about 37 °C	about 310 K
Absolute zero	−459.67 °F	−273.15 °C	0 K
Used by	US weather, cooking	most of the world; lab work	science; the SI unit

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8.2 Converting between scales

FORMULA BOX | Temperature formulas

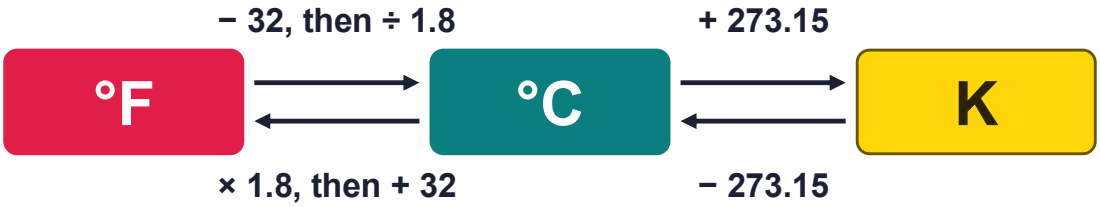
$$K = {}^\circ C + 273.15 \quad \textit{Celsius to kelvin}$$

$${}^\circ C = K - 273.15 \quad \textit{kelvin to Celsius}$$

$${}^\circ F = 1.8 \times {}^\circ C + 32 \quad \textit{Celsius to Fahrenheit}$$

$${}^\circ C = \frac{{}^\circ F - 32}{1.8} \quad \textit{Fahrenheit to Celsius}$$

1.8 and 32 are exact, and 273.15 is exact by definition. Some classes round 273.15 to 273; use whichever your teacher uses.



°C is the bridge: °F and K never convert directly

Celsius is the bridge between the other two scales. Top arrows run left to right (°F → °C → K). Bottom arrows run right to left (K → °C → °F). Order matters on the °F side: subtract 32 before dividing; multiply by 1.8 before adding 32.

WORKED EXAMPLE | Celsius to kelvin and back

Read	(a) Room temperature is 25.0 °C. Convert to K. (b) Liquid nitrogen boils at 77 K. Convert to °C.
Solve	(a) $K = 25.0 + 273.15 = 298.15 \rightarrow \mathbf{298.2\ K}$ *25.0 has one decimal place* (b) ${}^\circ C = 77 - 273.15 = -196.15 \rightarrow \mathbf{-196\ {}^\circ C}$ *77 has no decimal places*
Check	Kelvin numbers are always 273.15 bigger than Celsius numbers, and never negative.

SNEAK PEEK

From Sheet 7: which sig-fig rule do I use?

Every sheet turns a rule into a picture, a flowchart and a tiny example. This is the one students mix up most: adding versus multiplying.

ADD or SUBTRACT

line up the decimal points

$$\begin{array}{r} 12.6 \\ 0.358 \\ +\ 104.21 \\ \hline 117.168 \end{array}$$

unknown

answer: 117.2

keep the **FEWEST** decimal places (1)

MULTIPLY or DIVIDE

count sig figs in each number

$$4.52 \times 0.31$$

3 s.f. 2 s.f.

$$= 1.4012$$

answer: 1.4

keep the **FEWEST** sig figs (2)

Two operations, two different rules.

WHICH RULE? Ask these questions in order for every calculation.

Adding or subtracting? YES → Keep the **fewest decimal places**. Line the numbers up; the answer stops at the coarsest column.

then ask ↓

Multiplying or dividing? YES → Keep the **fewest significant figures** of any measured number.

then ask ↓

Is a number exact (counted or defined)? YES → Ignore it when choosing the limit: exact numbers have **unlimited** sig figs.

then ask ↓

More than one step? YES → Note the limit after each step but **keep every digit**. **Round once, at the end.**

NOTE | Regular or Honors?

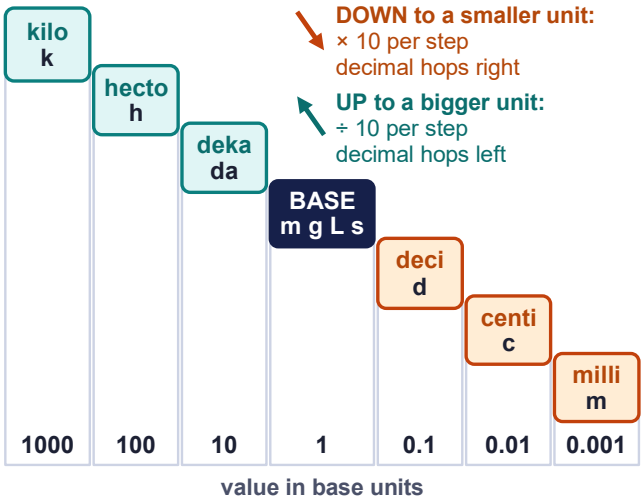
Anything in a navy box or tagged ★ HONORS is Honors only. Regular students can skip it.

SHEET 1 SI Units and Metric Prefixes

KEY IDEA A measurement is **a number + a unit**. Scientists use **SI** units, and a **prefix** in front of a unit multiplies it by a power of ten, so changing prefixes is just moving the decimal point.

SI base units	Length	Mass	Time	Temperature	Amount
Unit	meter	**kilogram**	second	kelvin	mole
Symbol	**m**	**kg**	**s**	**K** (no °)	**mol**

Prefix	giga	mega	kilo	*base*	deci	centi	milli	micro	nano
Symbol	**G**	**M**	**k**		**d**	**c**	**m**	**μ**	**n**
× unit	10^9	10^6	10^3	1	10^{-1}	10^{-2}	10^{-3}	10^{-6}	10^{-9}
Example	Gm	MW	km, kg	m, g, L	dL	cm	mm, mL	μg	nm



MEMORY TRICK | Staircase order

Kayla **H**as **D**one **B**ig **D**ance **C**lub **M**oves:

k · h · da · **Base** · d · c · m

EXAM TRAP | m, M and μ

m = milli, **M** = mega, **μ** = micro. **mm**, **Mm** and **μm** are very different lengths: copy capitals exactly.

PREFIX MOVE IN FOUR STEPS **e.g. 0.752 kg = 752 g (3 down) · 48 cm = 0.48 m (2 up)**

Count the steps between the two prefixes → **Which way?** DOWN to a smaller unit: decimal hops RIGHT → **Move the decimal** one hop per step; fill gaps with zeros → **Sense check** smaller unit = bigger number

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MINI EXAMPLE | Box: V = l × w × h

$$2.0\text{ cm} \times 3.0\text{ cm} \times 4.0\text{ cm}$$
$$= 24\text{ cm}^3 = 24\text{ mL} \quad \textit{2 s.f.}$$

EXAM TRAP | cm³ is not "cm × 3"

The little 3 means **cubed**. A cube 2 cm on each side holds 2 × 2 × 2 = **8 cm³**, not 6 cm³.

Density units: a solid's volume comes from ruler lengths (cm³); a liquid's from a cylinder (mL); gases are so spread out that they need the bigger liter (g/L). Since 1 mL = 1 cm³, g/mL and g/cm³ give the same number. Density calculations and multi-step conversions are in the Problem Solving set.

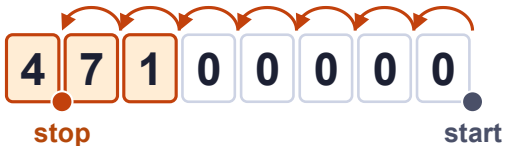
CAN YOU...? | Sheet 2 · answers at the back

1. A box is measured in centimeters. What unit will its volume have?
2. Write 125 cm³ in mL and in L.
3. Find the volume of a cube that is 3.0 cm on each side.
4. Which unit would you expect for the density of helium gas?

SHEET 3 Scientific Notation

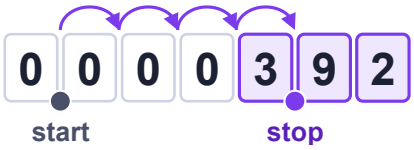
KEY IDEA A number is written as $a \times 10^n$ with 1 ≤ a < 10 and an integer n. Big numbers: **positive** exponent. Numbers below 1: **negative** exponent.

Big number 4.71×10^7



decimal hops 7 places LEFT → exponent +7

Small number 3.92×10^{-4}



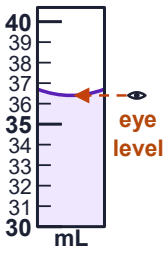
decimal hops 4 places RIGHT → exponent −4

Stop when exactly ONE nonzero digit is in front of the decimal point.

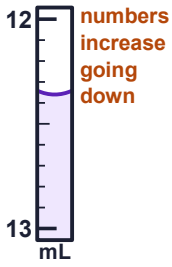
READING ANY MARKED SCALE

Value of one division (gap between labeled lines) ÷ (number of spaces) → **Read the certain digits** the last line the level has passed → **Estimate one more digit** one-tenth of a division → **Add the unit** mL, cm, °C, g

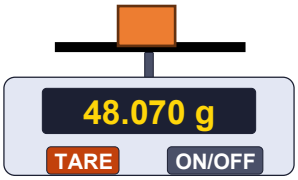
Instrument	Smallest mark	Read to	Example	Watch for
mm ruler	0.1 cm	0.01 cm	3.62 cm	start at the 0 line, not the end of the ruler
100 mL cylinder	1 mL	0.1 mL	36.4 mL	bottom of the meniscus, eye at liquid level
Buret	0.1 mL	0.01 mL	12.36 mL	0 is at the **top**: numbers grow downward
Thermometer	1 °C	0.1 °C	23.7 °C	wait for the reading to stop changing
Digital scale	shown	all digits	48.070 g	zero (tare) first; keep trailing zeros



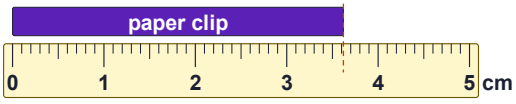
Cylinder: 36.4 mL



Buret: 12.36 mL



Balance: 48.070 g



Millimeter ruler: 3.62 cm



Thermometer, 1 °C marks: 23.7 °C

MINI EXAMPLE | Mixed steps: (24.68 − 21.3) × 1.75

$24.68 - 21.3 = 3.38$ *subtraction: 1 decimal place allowed, so 2 s.f. (3.4), but carry 3.38*

$3.38 \times 1.75 = 5.915$ *multiplication: keep the fewest s.f., which is 2*

$= 5.9$ *rounded once, at the end*

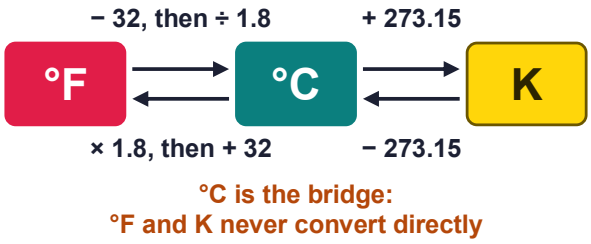
Rounding too early: 3.4 × 1.75 = 5.95 → **6.0**, wrong only because of rounding in the middle.

CAN YOU...? | Sheet 7 · answers at the back

1. Calculate 6.0 × 2.115 correctly.
2. Calculate 45.67 + 3.2 correctly.
3. Calculate 0.0360 ÷ 1.2 correctly.
4. Calculate (5.62 + 4.1) ÷ 2.00 correctly.

SHEET 8 Temperature Scales

KEY IDEA A **kelvin** is the same size as a **Celsius degree**, but the Kelvin scale starts at absolute zero, so it is **never negative**. **Celsius is the bridge** between °F and K.



FORMULA BOX | Temperature formulas

$K = {}^\circ C + 273.15$ *°C → K*

${}^\circ C = K - 273.15$ *K → °C*

${}^\circ F = 1.8 \times {}^\circ C + 32$ *°C → °F*

${}^\circ C = \frac{{}^\circ F - 32}{1.8}$ *°F → °C*

*1.8, 32 and 273.15 are exact (some classes use 273). Adding or subtracting follows the **decimal-place** rule.*

FREE PREVIEW · from 03 Exam Traps and Mistakes, page 3 of 46

SNEAK PEEK

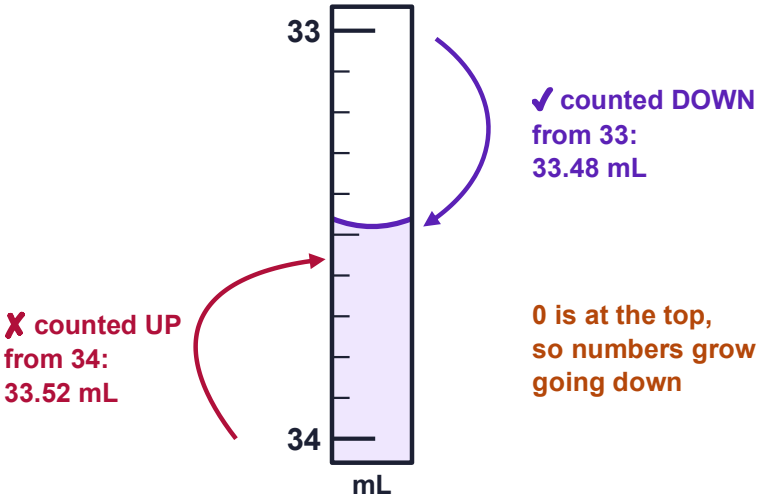
Every trap, wrong next to right

Three traps from inside, exactly as they appear in the guide: the mistake, the wrong working next to the right working, why it loses points, and a one-line rule so it never happens again.

EXAM TRAP READING INSTRUMENTS

Trap 22 · Reading a buret upward

The trap: The buret is read like a graduated cylinder, counting up from the bottom number.



A buret is numbered from the top down.

✗ WRONG	✓ RIGHT
"The level is 0.52 mL above the 34 mark." Reading: **33.52 mL**	0 is at the top; numbers grow going down. The level is 0.48 mL below the 33 mark. Reading: **33.48 mL**

Why it's wrong: A buret measures how much liquid has been **let out**, so its 0 mark is at the top. Counting upward from 34 reads the scale backward and puts the estimate on the wrong side.

HOW TO NEVER DO IT AGAIN On a buret, find the labeled number **above** the meniscus and count **down** from it. Read to 0.01 mL.

EXAM TRAP READING INSTRUMENTS

Trap 16 · Reporting a reading instead of a difference

The trap: The final reading is given as the amount used or added.

✗ WRONG	✓ RIGHT
Buret: start 1.20 mL, end 24.65 mL. Volume added = **24.65 mL** Beaker 48.31 g; beaker + salt 51.06 g. Mass of salt = **51.06 g**	Volume added = 24.65 mL − 1.20 mL = **23.45 mL** Mass of salt = 51.06 g − 48.31 g = **2.75 g**

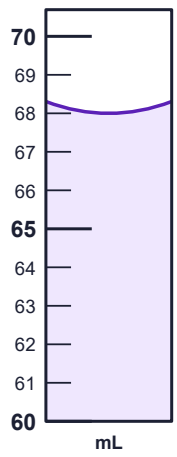
Why it's wrong: Burets rarely start at exactly 0.00 mL, and a container always has mass of its own. The amount delivered or added is the **change**: final minus initial.

HOW TO NEVER DO IT AGAIN Record both readings, then subtract: amount = final − initial (or use TARE with the container on the pan).

EXAM TRAP READING INSTRUMENTS

Trap 17 · Dropping an estimated zero

The trap: When the liquid sits exactly on a line, the zero is left off.

WHAT YOU SEE	✗ WRONG	✓ RIGHT
	The meniscus sits right on 68. Reading: **68 mL**	Marked every 1 mL, so read to 0.1 mL. Estimated tenths digit: 0. Reading: **68.0 mL**

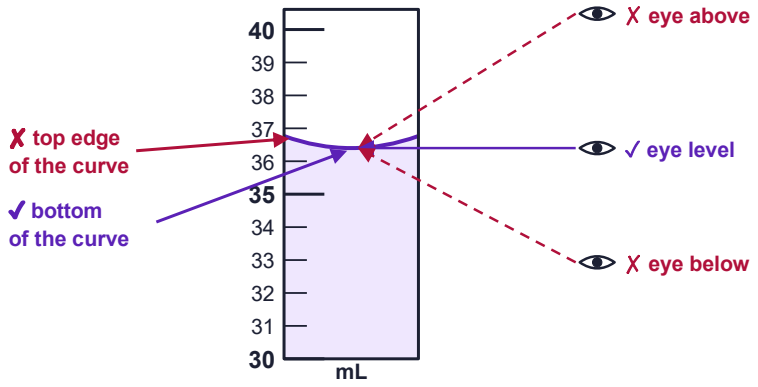
Why it's wrong: The final 0 is your estimated digit. It tells the reader "I checked the tenths place and it is zero". Without it, 68 mL looks like a reading made only to the nearest milliliter (2 s.f. instead of 3).

HOW TO NEVER DO IT AGAIN A zero you estimated is still a digit. Write it.

EXAM TRAP READING INSTRUMENTS

Trap 19 · Reading the meniscus from the wrong place

The trap: The top edge of the curved liquid surface is read, often while looking down at the cylinder.



Read the bottom of the curve with your eye level with it.

✗ WRONG	✓ RIGHT
Cylinder held up in one hand, read from above, at the top edge of the curve. Reading: **36.8 mL**	Cylinder on the bench, eye level with the liquid, bottom of the curve. Reading: **36.4 mL**

Why it's wrong: Water curves **down** in the middle; the volume is read at the bottom of that curve. Looking from above or below makes the surface line up with the wrong mark on the scale (parallax), and does it the same way every time, which is a systematic error.

HOW TO NEVER DO IT AGAIN Cylinder flat on the bench, crouch to eye level, read the bottom of the curve.

EXAM TRAP READING INSTRUMENTS

Trap 20 · Dropping zeros from a digital display

The trap: The trailing zero shown by a digital balance is left out.



A centigram balance display.

✗ WRONG	✓ RIGHT
Mass = **120.4 g** "The last zero doesn't matter."	Mass = **120.40 g** Copy every digit shown: 5 s.f.

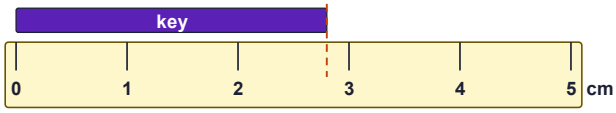
Why it's wrong: The balance measured to the hundredths place and found 0 hundredths. 120.4 g says you only know the mass to the nearest 0.1 g, which throws away a significant figure the instrument gave you.

HOW TO NEVER DO IT AGAIN Digital display: write down exactly what it shows, trailing zeros included. The balance has done the estimating for you.

EXAM TRAP READING INSTRUMENTS

Trap 21 · Writing more digits than the scale allows

The trap: Extra decimal places are added to look precise.



A ruler marked only in whole centimeters.

✗ WRONG	✓ RIGHT
Length of key = **2.83 cm** (or 2.825 cm)	Lines every 1 cm, so read to 0.1 cm. Certain: 2. Estimated: the 8. Length of key = **2.8 cm**

Why it's wrong: With marks only every centimeter, the tenths digit is already a guess. A hundredths digit would be a guess about a guess, so it has no meaning. **Only one** digit may be estimated.

HOW TO NEVER DO IT AGAIN Find the value of one division; your reading ends one place after it. No more, no less.

FREE PREVIEW · from 03 Exam Traps and Mistakes, page 32 of 46

PART 7 Temperature

Temperature conversions are short, so a single slip costs the whole answer. Celsius is the bridge: every conversion goes through °C.

Traps in this part: 40, 41, 42, 43, 44.

EXAM TRAP TEMPERATURE

Trap 40 · Adding or subtracting 273.15 the wrong way

The trap: The 273.15 is remembered, but not the direction.



Same temperature: K is always 273.15 BIGGER, and never below 0

The kelvin number is always the bigger one.

✗ WRONG	✓ RIGHT
37.0 °C → 37.0 − 273.15 = **−236.2 K** 215 K → 215 + 273.15 = **488 °C**	K = °C + 273.15 = 37.0 + 273.15 = 310.15 → **310.2 K** °C = K − 273.15 = 215 − 273.15 = −58.15 → **−58 °C**

Why it's wrong: For the same temperature, the kelvin number is always 273.15 **bigger** than the Celsius number. A negative kelvin value is impossible, so the first answer is clearly wrong.

HOW TO NEVER DO IT AGAIN To K: add 273.15. To °C: subtract 273.15. Check: is the K number the bigger one?

FREE PREVIEW · from 03 Exam Traps and Mistakes, page 41 of 46

The Top 10 Traps

If you only have ten minutes before the test, read this page. These are the ten slips that cost the most points.

#	The trap	✗ Wrong	✓ Right	The fix
1	**Counting leading zeros**	**0.0050 → 4 s.f.**	**0.0050 → 2 s.f.**	Leaders lie: start at the first nonzero digit.
2	**Dropping an estimated zero**	**68 mL**	**68.0 mL**	A zero you estimated is a digit. Write it.
3	**No estimated digit**	**7 mL**	**7.3 mL**	Estimate one-tenth of the smallest division.
4	**Wrong calculation rule**	**104.3 + 1.27 → 106**	**→ 105.6**	+ −: decimal places. × ÷: sig figs.
5	**Rounding in the middle**	**9.45 cm^3**	**9.46 cm^3**	Keep every digit; round once, at the end.
6	**273.15 the wrong way**	**37.0 °C → −236.2 K**	**→ 310.2 K**	To K, add. The K number is always bigger.
7	**°F formula order**	**98.6 − 32 ÷ 1.8**	**(98.6 − 32) ÷ 1.8**	To °C: subtract 32 first, then ÷ 1.8.
8	**Prefix moved the wrong way**	**2.75 km = 0.002 75 m**	**= 2750 m**	Smaller unit → bigger number.
9	**Exponent fixed the wrong way**	**52.7 × 10^3 = 5.27 × 10^2**	**= 5.27 × 10^4**	Coefficient down, exponent up.
10	**Reading a buret upward**	**33.52 mL**	**33.48 mL**	Count down from the number above.

MEMORY TRICK | Three rules that prevent half of all traps

- **Leaders lie, sandwiches stay, trailers need a point.**
- **Estimate one-tenth of the smallest division**, and write that digit even when it is 0.
- **Round once, at the end**, using + −: decimal places, × ÷: sig figs.

SNEAK PEEK

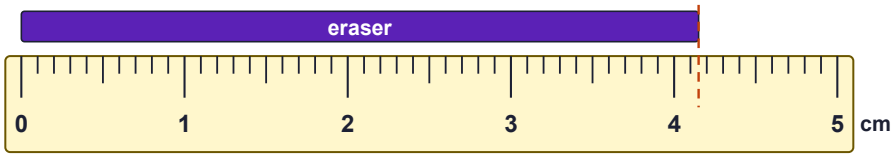
Every question has a full worked solution

Two questions taken straight from the bank, with their solutions exactly as they appear in the solutions section.

SAMPLE 1 | Read the instrument, Level 1

4.4 L1 WARM-UP READ THE INSTRUMENT

An eraser is lined up with a ruler marked in millimeters.



(a) What is the smallest division worth?

(b) To which decimal place should you report the length?

(c) Record the length of the eraser.

4.4 ANSWER (a) 0.1 cm (1 mm) (b) the hundredths place (c) 4.15 cm (4.14 to 4.16 cm is fine)

RULE Estimate to one-tenth of the smallest division.

$$\text{smallest division} = \frac{1\text{ cm}}{10\text{ spaces}} = 0.1\text{ cm} \quad \textit{(a)}$$

(b) One-tenth of 0.1 cm is 0.01 cm, so read to the **hundredths** place.

(c) The end of the eraser is past the 4.1 cm mark, about halfway to 4.2 cm. Certain digits **4.1**, estimated digit **5**:

$$\text{length} = \mathbf{4.15\text{ cm}} \quad \textit{3 s.f.}$$

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Topic 4 · Reading Lab Instruments

PART A · REGULAR

19 questions: L1 WARM-UP 6 L2 CORE 9 L3 CHALLENGE 4

Rulers, graduated cylinders, thermometers, burets and balances: certain digits plus one estimated digit. Readings: an answer within 1 of the key in the estimated digit is fine.

4.1 L1 WARM-UP MULTIPLE CHOICE

To read the volume of water in a graduated cylinder, you should read:

A the top of the meniscus, at eye level

B the bottom of the meniscus, at eye level

C the bottom of the meniscus, looking down from above

D the highest point the water touches on the glass

4.2 L1 WARM-UP FILL IN THE BLANKS

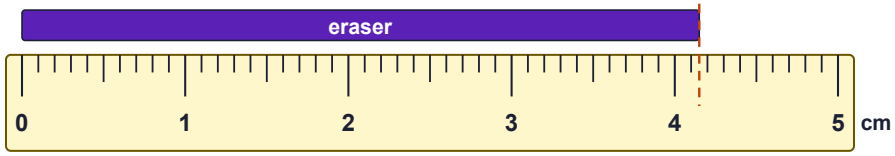
Fill in the blanks. On a marked scale, record every certain digit plus one estimated digit, about _____ of the smallest division. On a digital display, record _____ digit shown, including zeros at the end.

4.3 L1 WARM-UP TRUE OR FALSE

“A digital balance shows 3.50 g. You should record 3.5 g, because the final zero adds nothing.” *If false, correct it.*

4.4 L1 WARM-UP READ THE INSTRUMENT

An eraser is lined up with a ruler marked in millimeters.



(a) What is the smallest division worth?

(b) To which decimal place should you report the length?

(c) Record the length of the eraser.

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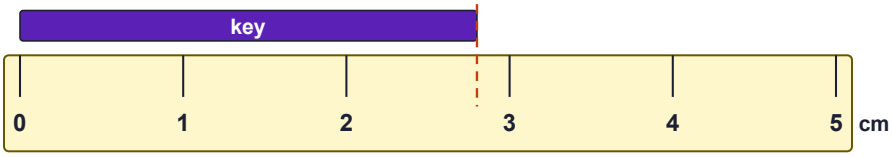
4.5 **L1 WARM-UP** **READ THE INSTRUMENT**

A key is lined up with a ruler marked only in whole centimeters.



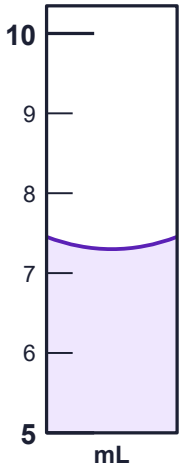
(a) Record the length of the key.

(b) How many significant figures does your reading have?

(c) Why would “2.80 cm” be the wrong way to record it?

4.6 **L1 WARM-UP** **READ THE INSTRUMENT**

Here is a graduated cylinder marked every 1 mL.



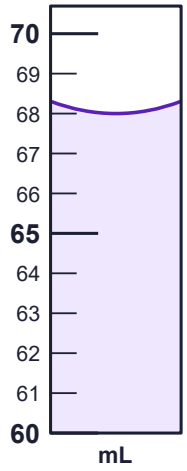
(a) What is each small division worth?

(b) To which decimal place should you read it?

(c) Read the volume.

4.7 L2 CORE READ THE INSTRUMENT

This cylinder is marked every 1 mL. The bottom of the meniscus sits right on a line.

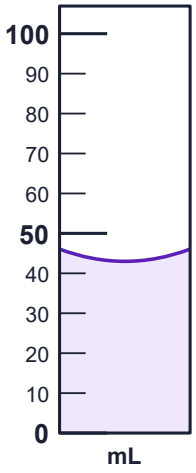


(a) Record the volume.

(b) A classmate writes “68 mL.” What is wrong with that?

4.8 L2 CORE READ THE INSTRUMENT

This large cylinder is marked every 10 mL.



(a) What is each division worth?

(b) Read the volume.

(c) How many significant figures does your reading have?

(d) Would a cylinder marked every 1 mL give a more or a less precise reading? Explain.

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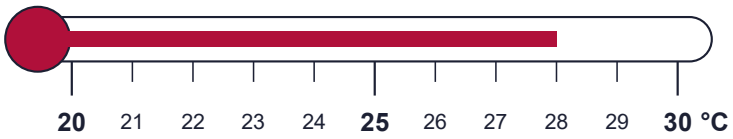
4.9 L2 CORE READ THE INSTRUMENT

A thermometer is marked every 1 °C.

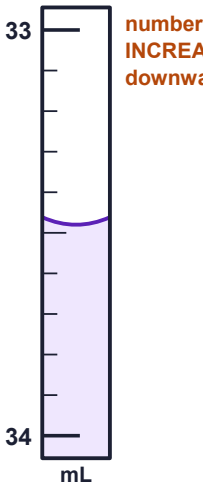


(a) Record the temperature.

(b) How many significant figures does your reading have?

4.10 L2 CORE READ THE INSTRUMENT

Here is part of a buret.



(a) Which way do the numbers on a buret increase?

(b) What is each small division worth?

(c) Record the reading.

4.11 L2 CORE READ THE INSTRUMENT

A digital balance shows this display.



(a) Record the mass.

(b) How many significant figures does the reading have?

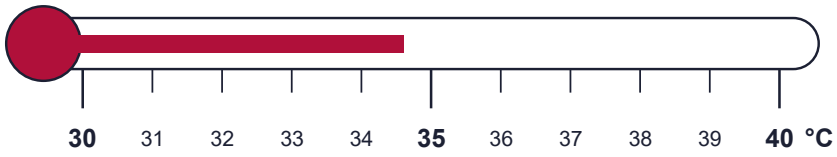
FREE PREVIEW · from 05 Practice Tests and Answer Keys, page 3 of 49

SNEAK PEEK

A real test question, graded the way a teacher grades

This sample is written in the style of Section C of the unit tests. Every question in the book is answered like this: the points, the full working, and the mistakes that cost points.

S The thermometer below is in a beaker of warm water. **[4 points]**



Thermometer marked every 1 °C.

(a) Record the temperature to the correct precision. **[1 point]**

(b) Convert your reading to kelvins. **[1 point]**

(c) Convert your reading to degrees Fahrenheit. **[2 points]**

How the points are awarded

Part	Correct answer and where the points go	Points
(a)	34.6 °C (accept 34.5 to 34.7). Lines are every 1 °C, so estimate to 0.1 °C.	B1
(b)	34.6 + 273.15 = 307.75 → 307.8 K (one decimal place, like 34.6; ecf from (a))	B1
(c)	multiplies by 1.8 **first**, then adds 32	M1
	94.3 °F	A1

Worked solution

$$K = 34.6 + 273.15 = 307.75 = \mathbf{307.8\ K}$$ *round to one decimal place*

$$°F = 1.8 \times 34.6 + 32 = 62.28 + 32 = 94.28 = \mathbf{94.3\ °F}$$ *1.8 and 32 are exact*

Common mistakes: writing 34 °C or 35 °C (no estimated digit); writing 307.8 °K; adding 32 before multiplying, which gives 119.9 °F.

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Quick Quiz B: Instruments, Accuracy and Significant Figures

Name _____ **Date** _____ **Class** _____ **Score** __ **/ 10**

INSTRUCTIONS | 10 minutes · 10 points · calculator allowed

- Circle the letter of the **one** best answer for multiple choice.
- Record instrument readings with every certain digit plus **one** estimated digit, and a unit.

1. A graduated cylinder is marked every 1 mL. Which reading is recorded correctly? [1 point]

A 24 mL **B** 24.3 mL **C** 24.35 mL **D** 24.350 mL

Questions 2 and 3 use the figures below.

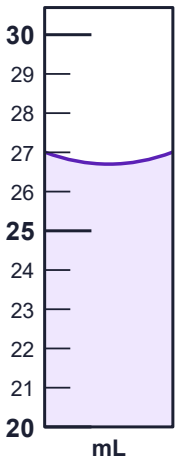


Figure 1 Graduated cylinder

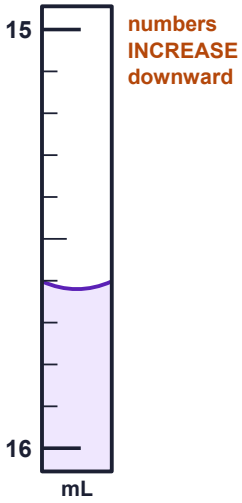


Figure 2 Buret

2. Volume in the graduated cylinder (Figure 1): _____ **[1 point]**

3. Reading on the buret (Figure 2): _____ **[1 point]**

FREE PREVIEW · from 05 Practice Tests and Answer Keys, page 15 of 49

SECTION C · CALCULATIONS AND INSTRUMENT READING

20 points. Show your working. Every answer needs a unit and the correct significant figures.

FORMULA BOX | Formulas given on this test

$$K = {}^{\circ}C + 273.15 \qquad {}^{\circ}F = 1.8 \times {}^{\circ}C + 32 \qquad {}^{\circ}C = \frac{{}^{\circ}F - 32}{1.8}$$

1.8, 32 and 273.15 are exact numbers.

21 Figure 1 shows an eraser against a ruler marked in millimeters. Figure 2 shows liquid in a graduated cylinder. **[3 points]**

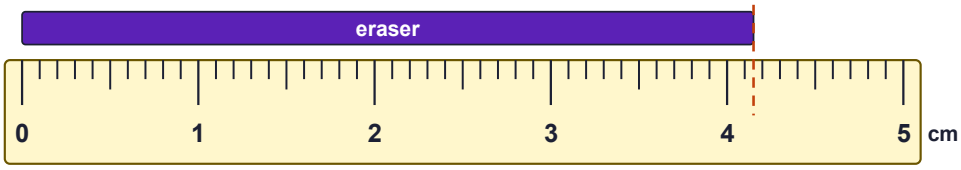


Figure 1

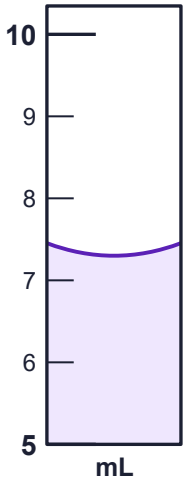


Figure 2

(a) Record the length of the eraser. **[1 point]**

Answer: .....

(b) Record the volume of liquid in the cylinder. **[1 point]**

Answer: .....

SNEAK PEEK

A slice of the glossary and two real cards

Every glossary entry has a topic tag in the color of its flashcards, so you always know where a word belongs. BASICS terms (such as Unit and Quantitative observation) have no flashcards of their own:

UNITS & PREFIXES SCI NOTATION INSTRUMENTS
ACCURACY & PRECISION SIG FIGS TEMPERATURE ★ HONORS

Term	Plain-English definition	Example
Meniscus INSTRUMENTS	The curved surface of a liquid in a narrow tube. Water curves down, so read the bottom of the curve at eye level.	Reading 7.3 mL at the bottom of the curve
Exact number SIG FIGS	A number with no uncertainty: counted or defined. It has unlimited significant figures and never limits an answer.	24 students; 1 m = 100 cm; 1 in = 2.54 cm
Systematic error ACCURACY & PRECISION	Error that pushes every reading the same way (all high or all low). Lowers accuracy; averaging does not help.	A balance that reads 0.30 g with nothing on it
Percent error ★ HONORS	Compares a measured value with the accepted value: |measured − accepted| ÷ accepted × 100%. Measures accuracy.	Measured 8.72, accepted 8.96 g/cm^3: 2.7% error

Two cards, front and back. (In the printable sheets the answers sit on the back of the page.)

SIG FIGS S3 **How many s.f. in 0.00450?**	S3 · SIG FIGS **3** Leading zeros no; the trailing zero after the decimal point yes.
TEMPERATURE T4 **Convert 25 °C to K**	T4 · TEMPERATURE 25 + 273.15 = 298.15 → **298 K** 25 has no decimal places.

Regular flashcards · Sheet 1 of 9 · FRONT *questions · cut on the dashed lines*

UNITS & PREFIXES U1

What does SI stand for?

UNITS & PREFIXES U2

SI base units for length, mass, time and temperature (name and symbol)

UNITS & PREFIXES U3

Which SI base unit has a prefix built into its name?

UNITS & PREFIXES U4

Mass vs. weight

UNITS & PREFIXES U5

kilo- (k) = ?

UNITS & PREFIXES U6

centi- (c) = ?

UNITS & PREFIXES U7

milli- (m) = ?

UNITS & PREFIXES U8

micro- (μ) and nano- (n) = ?

UNITS & PREFIXES U9

Memory hook for the metric staircase, kilo down to milli

UNITS & PREFIXES U10

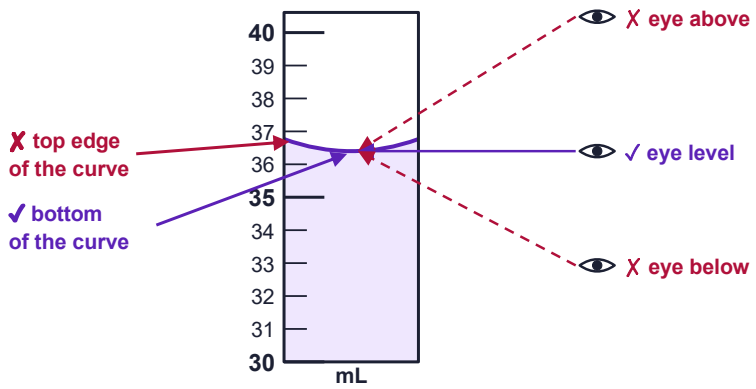
Convert 4.2 km to meters

FREE PREVIEW · from 07 Lab Skills for Tests, page 7 of 25

MEMORY TRICK | The one rule behind every reading

Marked scale: write every certain digit, then estimate **one-tenth of the smallest division** by eye. If the level sits exactly on a line, the estimated digit is a **0**, and you still write it.

Digital display: write **every digit shown**, zeros included. Never add or drop a digit.



Read the bottom of the curve, with your eye level with it.

WORKED EXAMPLE | Reading a graduated cylinder

1 Value of one division	The labeled lines 35 and 40 mL are 5 spaces apart, so one division is $\frac{40-35}{5}$ = 1 mL. Read to one-tenth of that: **0.1 mL**.
2 Where to look	Eye level with the liquid. Read the **bottom** of the curved surface (the meniscus), not the top edge where the water climbs the glass.
3 Certain digits	The bottom of the curve is past the 36 line but not at 37: the **36** is certain.
4 Estimated digit	It sits about four-tenths of the way to 37, so the reading is **36.4 mL**. A classmate who writes 36.3 or 36.5 mL read it correctly too; 36 mL or 36.40 mL has the wrong number of decimal places.

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Instrument	Smallest marking (typical)	Read to	Example
Ruler marked in mm	0.1 cm	0.01 cm	4.15 cm
Ruler marked in cm only	1 cm	0.1 cm	2.8 cm
100 mL graduated cylinder	1 mL	0.1 mL	36.4 mL
50 mL buret	0.1 mL	0.01 mL	12.36 mL
Lab thermometer	1 °C	0.1 °C	23.7 °C
Centigram balance	digital	every digit shown	48.07 g

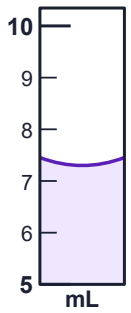
EXAM TRAP | Burets count downward

A buret has 0 at the **top**. As liquid leaves, the level drops and the readings get **bigger**. A level just below the 33 line reads 33.something mL, not 32.something. Volume delivered = final reading − initial reading.

Read the graduated cylinders

For each item, write the value of one division, then the reading. The key accepts an estimated digit that is off by one (7.2 or 7.4 mL for 7.3 mL), but not a wrong number of decimal places.

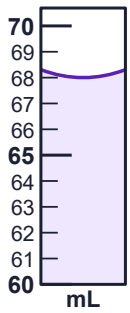
ITEM 1 Cylinder



Division: _____ mL

Reading: _____ mL

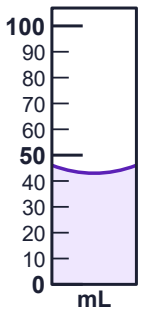
ITEM 2 Cylinder



Division: _____ mL

Reading: _____ mL

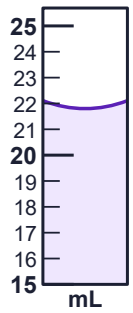
ITEM 3 Cylinder



Division: _____ mL

Reading: _____ mL

ITEM 4 Cylinder



Division: _____ mL

Reading: _____ mL

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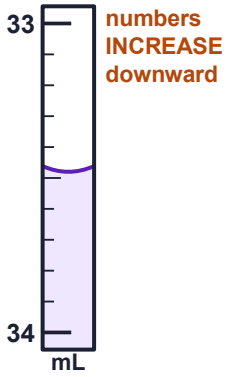
Read the burets and balances

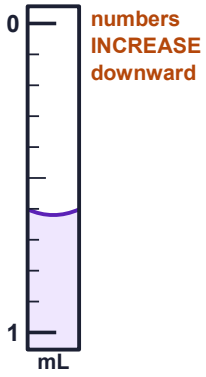
ITEM 11 Buret



Smallest division: _____

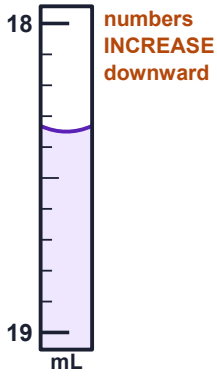
Reading: _____ mL

ITEM 12 Before



Initial reading: _____ mL

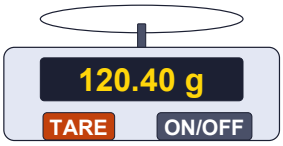
ITEM 12 After



Final reading: _____ mL

Volume delivered: _____ mL

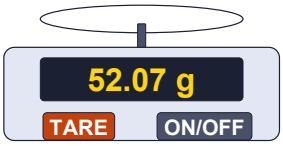
ITEM 13 Digital balance



Reading: _____ g

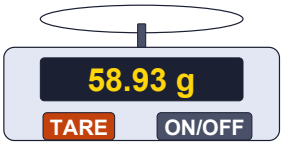
Sig figs: _____

ITEM 14 Empty beaker



Reading: _____ g

ITEM 14 Beaker + salt



Reading: _____ g

Mass of salt: _____ g

Recording Data

Tests often show a data table and ask what is wrong with it. A correct table lets anyone see what was measured, with what, and how carefully.

- **Units go in the column heading**, like "Volume (mL)". Then only numbers go in the cells.
- **Every reading gets exactly one estimated digit:** one-tenth of the smallest division on a scale, or every digit shown on a digital display.
- **Keep the trailing zeros you measured.** 36.0 mL and 12.70 cm say "I checked that place"; 36 mL and 12.7 cm say less.

FREE PREVIEW · from 07 Lab Skills for Tests, page 12 of 25

Data set A Two rulers, the same objects

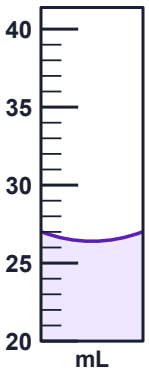
Ruler A is marked in **whole centimeters only**. Ruler B is marked in **millimeters** (0.1 cm).

Object	Ruler A (cm)	Ruler B (cm)
Pencil	17.6	17.62
Index card (long side)	12.7	12.70
Paper clip	3.2	3.18
Coin (diameter)	2.40	2.43

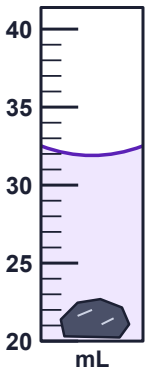
1. In the Ruler A reading for the pencil, 17.6 cm, which digit is estimated?
2. How many significant figures does each ruler give for the pencil? Why does Ruler B give one more?
3. One entry in the Ruler A column is recorded with the wrong precision. Find it and correct it.
4. For the index card, why must the student write 12.70 cm with Ruler B, not 12.7 cm?

Data set B Volume by water displacement

A student read a graduated cylinder before and after sliding a rock into it, then did the same with a bolt and a small cube. With a millimeter ruler, the cube measured **1.52 cm** on each edge.



Before: water only



After: rock added

Object	Initial (mL)	Final (mL)
Rock	see picture	see picture
Bolt	25.0	28.6
Cube	30.0	33.5

1. Read both cylinder pictures, then find the volume of the rock in cm^3.
2. Find the volumes of the bolt and the cube.

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