# Measurements

**SQ 1.1 What are base units and derived units? Give some examples of both these units.**

### Base Units

Base units are independent standards from which other units are formed.

### Examples

metre (m), kilogram (kg), second (s), ampere (A), kelvin (K), mole (mol), and candela (cd).

### Derived Units

Derived units are obtained by combining base units.

### Examples

Velocity has unit $\mathrm{m\,s^{-1}}$.
Force has unit newton (N), equivalent to $\mathrm{kg\,m\,s^{-2}}$.
Energy has unit joule (J), equivalent to $\mathrm{kg\,m^2\,s^{-2}}$.

**SQ 1.2 How many significant figures should be retained when multiplying or dividing, and when adding or subtracting numbers?**

### Multiplication or Division

Retain as many significant figures as the factor having the fewest significant figures.

### Addition or Subtraction

Retain as many decimal places as the term having the fewest decimal places.

**SQ 1.3 How is the Vernier scale related to the main scale of a Vernier Callipers? What is meant by L.C. of the Vernier Callipers?**

### Vernier Scale Relation

Usually $n$ Vernier divisions equal $(n-1)$ main-scale divisions.

### Least Count

The least count is the smallest length that the instrument can reliably measure. Therefore,

$$\text{least count} = 1\,\text{MSD} - 1\,\text{VSD} = \frac{1\,\text{MSD}}{n}.$$

**SQ 1.4 Write the following numbers in scientific notation: (a) 143.7 (b) $206.4 \times 10^7$.**

$143.7 = 1.437 \times 10^2$,
$206.4 \times 10^7 = 2.064 \times 10^9$.
In scientific notation, the coefficient must be at least 1 and less than 10: $1 \leq a < 10$.

**SQ 1.5 Write the following numbers using correct prefixes: (a) $580 \times 10^2\,\mathrm{g}$ (b) $0.45 \times 10^{-5}\,\mathrm{s}$.**

### Using the appropriate SI prefixes

### Part (a)

$580 \times 10^2\,\mathrm{g} = 58 \times 10^3\,\mathrm{g} = 58\,\mathrm{kg}$.

### Part (b)

$0.45 \times 10^{-5}\,\mathrm{s} = 4.5 \times 10^{-6}\,\mathrm{s} = 4.5\,\mu\mathrm{s}$.

**SQ 1.6 Kinetic energy of a body of mass $m$ moving with speed $v$ is given by $\frac{1}{2}mv^2$. What are the dimensions of kinetic energy?**

### Mass

$[m] = [M]$

### Velocity

$[v] = [LT^{-1}]$

### Kinetic Energy

$[KE] = [M][LT^{-1}]^2 = [ML^2T^{-2}]$.
The required dimensions are mass, length squared, and inverse time squared.

**SQ 1.7 How many significant figures are in 37 km, 0.002953 m, 7.50034 cm, and 200.0 m?**

### 37 km

2 significant figures.

### 0.002953 m

4 significant figures because leading zeros are not significant.

### 7.50034 cm

6 significant figures.

### 200.0 m

4 significant figures because the decimal point makes the trailing zeros significant.

**SQ 1.8 Write the dimensions of Planck's constant and angular velocity.**

### Planck's Constant

From the energy-frequency relation
$E = hf$
$[h] = [E][f]^{-1} = [ML^2T^{-1}]$.

### Angular Velocity

Angle is dimensionless, so angular velocity has the dimensions
$[\omega] = [T^{-1}]$.

**CRQ 1.1 Why is it useful to have kilogram and mole as units for the amount of material?**

### Kilogram

It measures the mass of a substance.

### Mole

It measures the number of entities;
$1\,\text{mol} = 6.022 \times 10^{23}\,\text{entities}$

### Need for Both

Equal masses of different substances generally contain different numbers of particles, so both units are required.

**CRQ 1.2 A scale has 1 mm minimum divisions. Students record a rod length as 0.4235 m, 0.42 m, and 0.424 m. Which record is correct and why?**

### Least Count

$1\,\text{mm} = 0.001\,\text{m}$
so the reading should have three decimal places in metres.

### Correct Reading

$0.424\,\text{m}$ is consistent with the instrument.

### Reason

$0.4235\,\text{m}$ claims unjustified precision, while $0.42\,\text{m}$ discards available precision.

### CRQ 1.3 Why is kilogram, rather than gram, the SI base unit of mass?

**SI Base Unit**

The kilogram was historically selected as the coherent base unit suitable for practical masses.

**Coherent Unit**

Mechanical units follow consistently; for example,
$1\,\mathrm{N} = 1\,\mathrm{kg\,m\,s^{-2}}$
The gram remains a submultiple with a value of $10^{-3}\,\mathrm{kg}$.

### CRQ 1.4 For $P = Q + R$, if $Q$ and $R$ both have dimensions $[MLT^{-1}]$, find the dimensions and SI unit of $P$. What if their dimensions differ?

**Condition for Addition**

Only quantities with identical dimensions can be added.

**Dimensions of P**

$$[P] = [Q] = [R] \\ = [MLT^{-1}]$$

**SI Unit**

$\mathrm{kg\,m\,s^{-1}}$.

**Different Dimensions**

The equation would be dimensionally invalid, so $P$ could not be assigned dimensions from the sum.

### CRQ 1.5 What is the least count of a clock with (a) hour, minute, and second hands, and (b) hour and minute hands?

**Least Count**

The smallest marked time interval that can be read directly.

**Hour, Minute and Second Hands**

Normally $1\,\mathrm{s}$.

**Hour and Minute Hands**

Normally $1\,\mathrm{min}$ for a clock with usual graduations.

### CRQ 1.6 How can the diameter of a round pencil be measured with a metre rule with accuracy comparable to Vernier callipers?

**Method**

Place $N$ identical pencils tightly side by side and measure their total width $W$.

**Diameter of One Pencil**

$$d = \frac{W}{N}.$$

**Advantage**

Measuring many diameters together reduces fractional uncertainty approximately by the factor $N$.

### CRQ 1.7 How would readings differ if a screw gauge were used instead of Vernier callipers to measure a glass plate's thickness?

**Vernier Callipers**

The least count is typically about $0.1\,\mathrm{mm}$.

**Screw Gauge**

Its smaller least count is typically $0.01\,\mathrm{mm}$, giving more meaningful decimal places and less instrumental uncertainty.

**Result**

After correcting zero error, both measurements should agree within their uncertainties.

### CRQ 1.8 How is the correct Vernier reading found when the instrument has a positive zero error of $+0.02\,\mathrm{cm}$?

**Observed Reading**

$R_{obs} = R_{main} + (n \times LC)$.

**Zero Correction**

A positive zero error requires a negative correction.

**Correct Reading**

$R_{correct} = R_{obs} - 0.02\,\mathrm{cm}$.

**Diagram Values**

Use the main-scale reading and coinciding Vernier division shown in the exercise figure.

### CRQ 1.9 A screw gauge has 50 circular divisions and advances 5 mm in 10 revolutions. Explain how to find the corrected glass-slab thickness when the second division gives a positive zero error.

**Pitch**

$5/10 = 0.5\,\mathrm{mm}$

**Least Count**

$$LC = \frac{0.5}{50} = 0.01\,\mathrm{mm}.$$

**Zero Error**

The positive zero error is
$2(0.01) = 0.02\,\mathrm{mm}$

**Corrected Thickness**

For main-scale reading $M$ and circular coincidence $n$
$t = M + n(0.01) - 0.02\,\mathrm{mm}$.
Apply the negative correction for positive zero error.

### CRQ 1.10 What is a dimensionless quantity? Give an example.

**Dimensionless Quantity**

A quantity with no physical dimensions because like dimensions cancel.

**Dimensional Formula**

$[M^0L^0T^0]$.

**Examples**

Refractive index $n$ is the ratio $c/v$.
Strain is the ratio $\Delta L/L$.
Other examples are coefficient of friction and plane angle measured in radians.

### CRQ 1.11 A paper is folded three times and its total thickness is measured with a screw gauge. How is the thickness of one sheet found?

**Number of Layers**

Three folds produce eight layers because the number of layers is $2^3$, which is 8.

**Corrected Reading**

Correct the screw-gauge reading for any zero error.

**Thickness of One Sheet**

$$t_{sheet} = \frac{t_{folded}}{8}.$$

The folded thickness comes from the main and circular scales shown in the figure.

**CRQ 1.12** **Round 0.02055 and 4656.5 to three significant figures and write them in scientific notation.**

### For 0.02055

$$0.02055 = 2.055 \times 10^{-2}$$

$0.02055$ (to 3 s.f.) $= 2.06 \times 10^{-2}$

### For 4656.5

$$4656.5 = 4.6565 \times 10^{3}$$

$4656.5$ (to 3 s.f.) $= 4.66 \times 10^{3}$

### Rule

Use the first discarded digit to round the last retained digit.