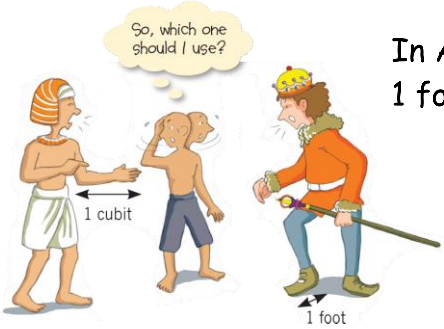
**Chapter 2** **Date: ____________**

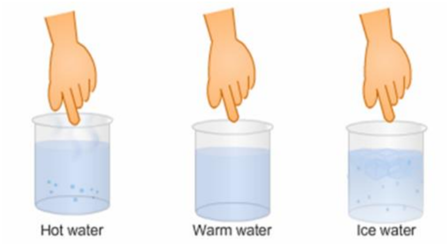
# Exploring Diversity of Matter by its Physical Properties

Did you know?

In Ancient **Egypt**,
1 cubit = length of
elbow to middle finger




In Ancient **Europe**,
1 foot = length of the King's foot
(from toe to heel)




We cannot use our five senses to take accurate measurements!

We need measuring instruments to take measurements accurately.

## 1 Physical Quantities

- Physical quantity is a **quantity** that can be measured by specific scientific instruments. E.g. length, volume, time and temperature
- **Measurements** are expressed in two parts: numerical and unit. E.g. 21 metres or 15 kilograms
- The International System of Units, **SI units** (*Systeme Internationale d' Unites* in french) was used to overcome the problems of different units of measurement.
    - This ensures a standard of units used in scientific measurement recognised internationally.

### 1.1 Base quantities and Derived quantities

- There are *seven* **basic quantities** commonly used in measurements.

| Base quantity | Name of unit | Symbol of unit |
|---|---|---|
| length | metre | |
| mass | kilogram | |
| time | second | |
| electric current | ampere | |
| temperature | kelvin | |
| amount of substance | mole | |
| luminous intensity | candela | |

- Base quantities can be used together to measure other **physical quantities** also known as ***derived quantities***.

  Some examples of **derived quantities**

| Derived quantity | S.I unit | Symbol of unit |
|---|---|---|
| area | square metre | |
| volume | cubic metre | |
| density | kilogram per cubic metre | |
| speed | metre per second | |

## 1.2 Prefixes

- To manage large and small scale measurements, **prefixes** were introduced.

| Prefix | Symbol | Meaning |
|---|---|---|
| Tera | T | X 1 000 000 000 000 |
| Giga | G | X 1 000 000 000 |
| Mega | | |
| | k | |
| hecto | h | X 100 |
| deca | da | X 10 |

| Prefix | Symbol | Meaning |
|---|---|---|
| | d | |
| | c | |
| milli | | ÷ 1 000 |
| micro | | ÷ 1 000 000 |
| nano | n | ÷ 1 000 000 000 |
| pico | | ÷ 1 000 000 000 000 |

Examples:

a) Convert 2.5 Gb to bytes, b.

2.5 Gb = 2.5 x 1 000 000 000 b
= 2 500 000 000 b

b) Convert 3 μm to metres, m.

3 μm = 3 ÷ 1 000 000 m
= 0.000 000 3 m

c) Convert 1.6 km to metres, m.

1.6 km = 1.6 ………………….
= 1 600 m

d) Convert 0.5 mm to metres, m.

0.5 mm = 0.5 …………………….
= 0.000 5 m

e) Convert 0.25 Tb to bytes, m.

f) Convert 125 ps to seconds, s.

## 2 Measuring length

- SI unit: **metres** Symbol: **m**
- Other common units of length:
  - Centimetre (**cm**): 1 cm = **0.01** m
  - Millimetre (**mm**): 1mm = 0.001 m
  - Kilometre (**km**): 1 km = 1000 m

Unit conversions:

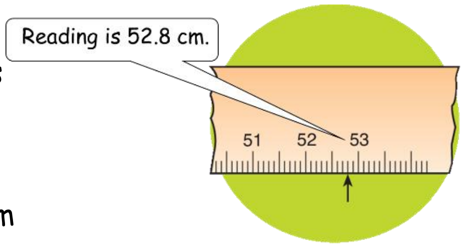
| | | | |
|---|---|---|---|
| a) | 1 km | = | 1000 m |
| b) | 2.6 km | = | …………………… m |
| c) | 2 m | = | 200 cm |
| d) | 3.2 m | = | …………………… cm |
| e) | 25 cm | = | 250 mm |
| f) | 162 mm | = | …………………… m |

- **Common instruments** used to measure lengths: ruler, half-metre rule or a metre-rule, measuring tapes, Vernier calipers and micrometer screw gauge.

**Accuracy of readings:** instruments typically have marks dividing them into smaller units or measurements.

*Example*: Metre rules and measuring tapes divides into centimetres and millimetres.

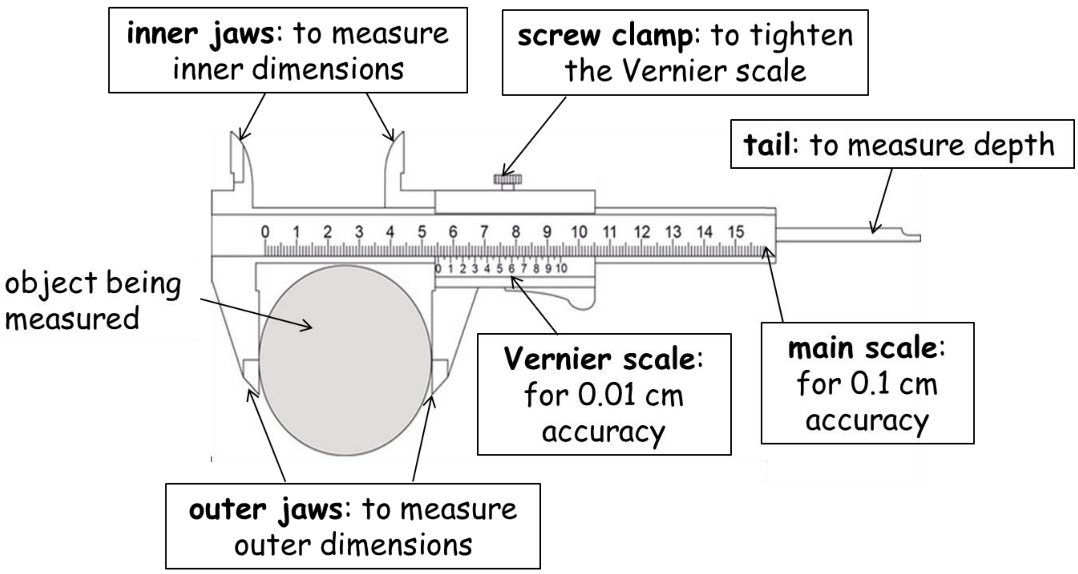
- Smallest division: 1 mm
- Readings are accurate to 1mm



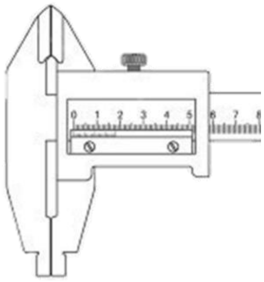

### 2.1 Vernier Calipers

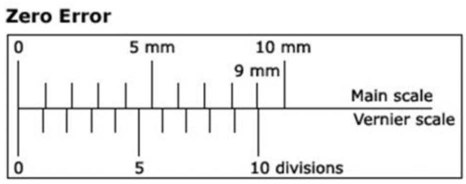
- Accuracy: up to **two decimal places**; 0.01 cm
- It is more accurate than a metre rule because a metre rule can measure up to **one decimal place** (0.1 cm).

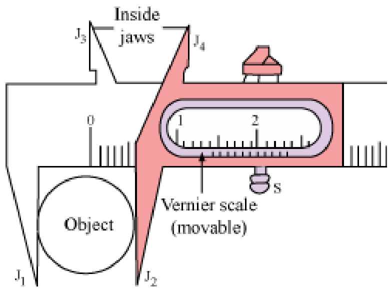
**Parts of a Vernier caliper**:



## How to use a Vernier caliper?






1. Close the jaws

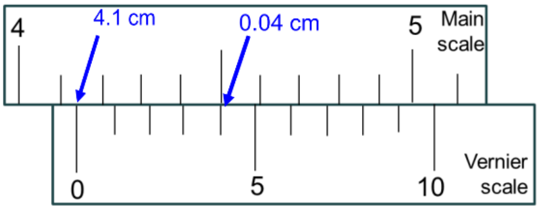
2. Check and record for zero error

3. Adjust jaws for object

4. Locate the zero mark on the Vernier scale. Record the **main scale reading**.

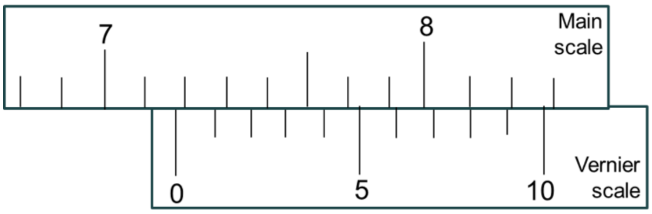
5. Locate the **line of intersection** created by the markings on the main scale with the Vernier scale. Record the **Vernier scale reading**.

6. Add the main and Vernier scale readings together.



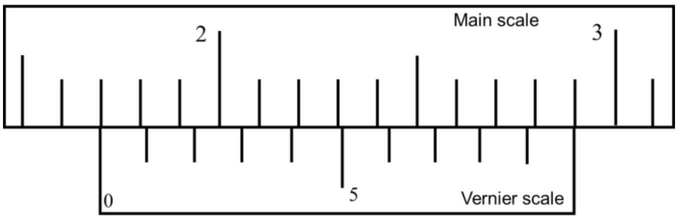

Main scale reading = 4.1 cm
Vernier scale reading = 0.04 cm
Actual reading = 4.14 cm

Example 1:




Main scale reading = _______ cm
Vernier scale reading = ______ cm
Actual reading = _______ cm

Example 2:

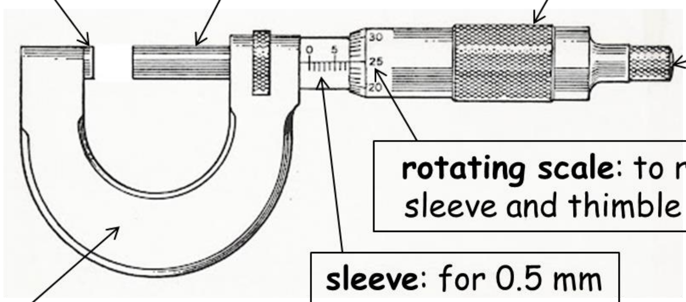



Main scale reading = _______ cm
Vernier scale reading = ______ cm
Actual reading = _______ cm

### 2.2 Micrometer screw gauge

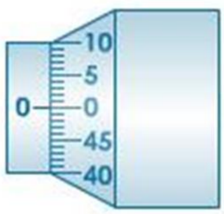
- Accuracy is up to 0.001 cm (**three decimal places**)
- Measurements are taken in **millimetre**; 0.01 mm.
- Micrometers measure small diameters or thicknesses, e.g thickness of hair or needles.

**Parts of a micrometer screw gauge**

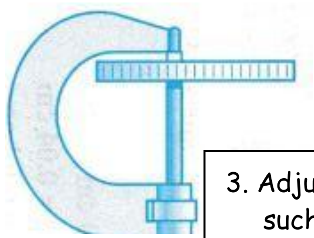



**How to use a micrometer screw gauge?**


such that the anvil and spindle meet.




2. Check and record for zero error.

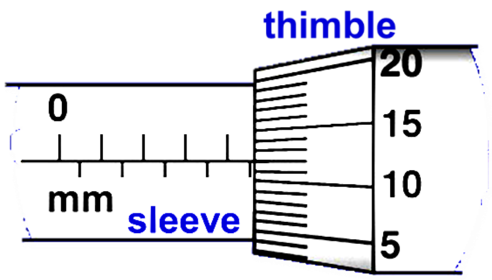


3. Adjust the thimble such that the object is between the anvil and the spindle.

4. Locate where the thimble meets the sleeve. Record the sleeve reading.

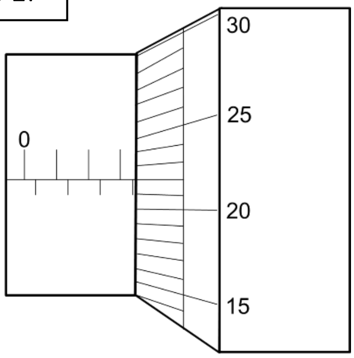
5. Locate the interception between the sleeve and the thimble. Record the thimble reading.

6. Add sleeve and thimble readings together.



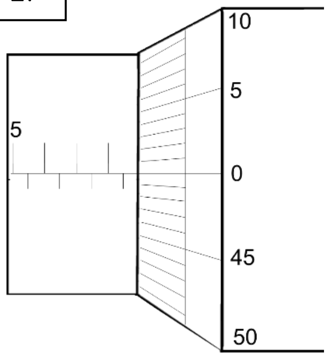

Sleeve reading = 4.5 mm
Thimble reading = 0.12 mm
Actual reading = 4.62 mm = 0.462 cm

Example 1:




Sleeve reading = _______ mm
Thimble reading = ______ mm
Actual reading = _______ mm =_______ cm

Example 2:




Sleeve reading = _______ mm
Thimble reading = ______ mm
Actual reading = _______ mm =_______ cm

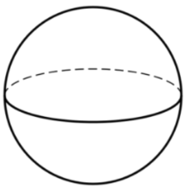
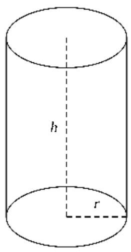
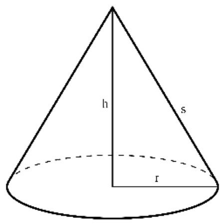
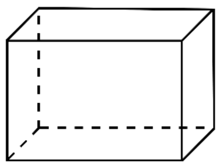
## 3 Measuring volume

- Volume is the amount of space a substance occupies.
- SI Unit: cubic metre
- Symbol: $m^3$

- Other common units of volume:
  - Millilitres (m*l*) : 1m*l* = 1 $cm^3$ = **0.000 001** $m^3$
  - Litres (*l*): 1*l* = 1000 m*l* = **1 000** $cm^3$
  - Cubic centimetre (**$cm^3$**): 1 $cm^3$ = **0.000 001** $m^3$

### (a) Volume of regular solids

- Volumes of regular solids

| **Object** | **Sphere** | **Cylinder** | **Cone** | **Cuboid** |
|---|---|---|---|---|
| **Diagram** |  |  |  |  |
| **Formula** | $V = \frac{4}{3}\pi r^3$ | $V = \pi r^2 h$ | $V = \frac{1}{3}\pi r^2 h$ | $V = l \times b \times h$ |

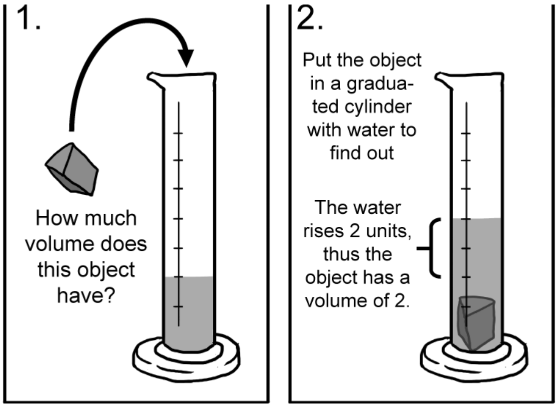
**(b) Volume of irregular solids**

- Measured with "water displacement method".

1. Lower object carefully into a measuring cylinder containing water, water level rises.

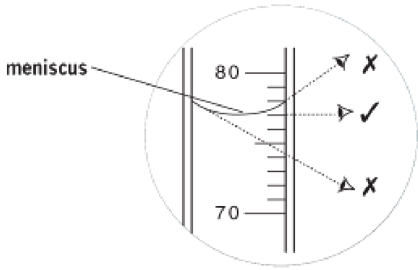
2. Water is displaced by the solid

3. Volume of solid = volume of water displaced




**(c) Volume of liquids**

- To find the volume of liquids, we make use of instruments like measuring cylinder and beaker.
- The liquid surface is a little curved, called a **meniscus**.
- To **avoid parallex error**, your eyes must be at the same level as the curved part of the meniscus.




**4 Measuring mass**

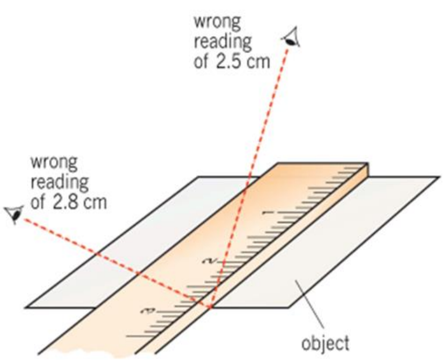
- Mass is the amount of substance packed in the object.
- SI unit: Kilogram
- Symbol: kg

Other common units of volume:
- Tonnes ( t ) : 1 t = 1 000 kg = **1 000 000** g
- Grams ( g ): 1 000 g = 1 kg
- Milligrams ( mg ): 1 mg = 0.001 g
  = 0.000 001kg

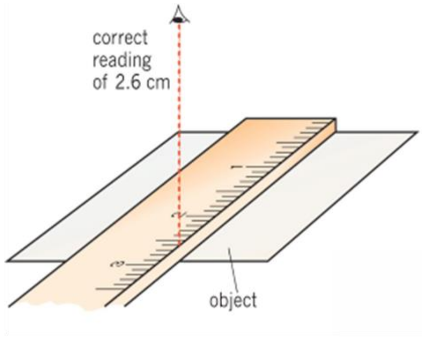
- Instruments to measure mass: double beam balance and electronic mass balance.

## 5 Accuracy, Precision and Errors

**a)** **Parallex error** is an error made in measurements when the **eye** is positioned wrongly.



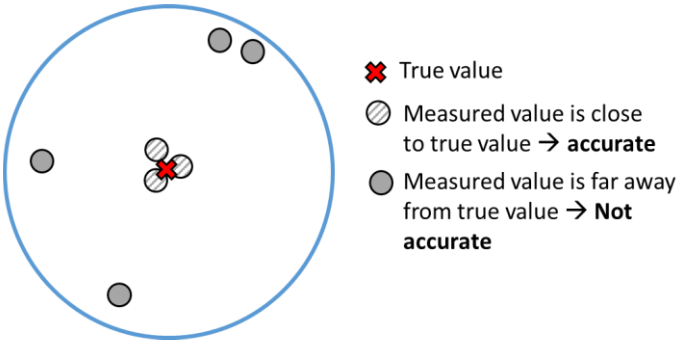

Parallax error

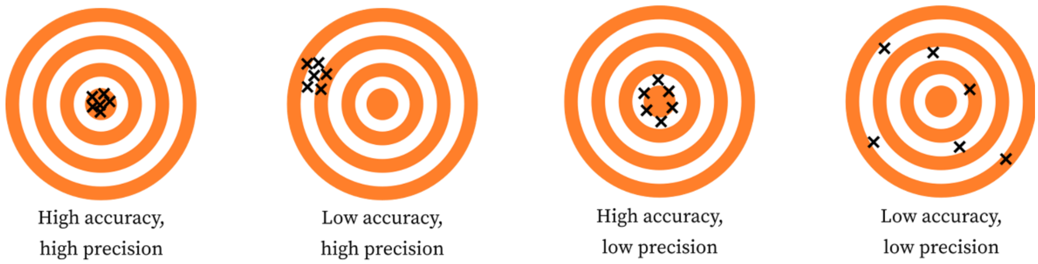



No parallax error

**b)** **Accuracy of measurements** refers to the **closeness of agreement** between the **measured value** and the **true value** of what is being measured.

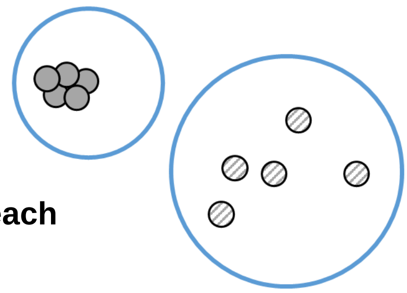
- If the measured value is **very close to the true value** the measurement is **<u>accurate</u>**.
- If the measured value is **far away from the true value** the measurement is **<u>not accurate</u>**.




**c)** **Precision of measurement** refers to the **closeness of agreement** between **measured values** obtained by **<u>repeated measurements</u>**.

- If the <u>repeated</u> measured value are **very close to each other** the measurement is **<u>precise</u>**.
- If the <u>repeated</u> measured value are **far away from each other** the measurement is **<u>not precise</u>**.



## d) Types of Error

| | |
|---|---|
| **Zero** | Zero error is a type of error in which **an instrument gives a non-zero reading** when the measured quantity should be zero.<br><br>*Example:* If a weighing machine shows a reading (e.g. 0.25 kg) when there is nothing placed on it, the weighing machine is described to have zero error. |
| Errors that are **consistent**<br>↓<br>**<u>Systematic</u> error** | Consistent error is a type of error that **differs by a fixed amount** from the true value of measurement.<br><br>*Example*: If a weighing machine has zero error (e.g. 0.25 kg), all readings taken on this instrument will be consistently 0.25 kg more. (e.g. an object of true mass 1 kg will read 1.25 kg and an object of true mass 5.5 kg will read 5.75 kg) |
| Errors that are **unpredictable**<br>↓<br>**<u>Random</u> error** | Unpredictable error is a type of error that **fluctuate** caused by factors which <u>vary from one measurement to another</u>. Some factors are unpredictable environmental conditions or human reaction time in operating a stopwatch.<br><br>*Examples*:<br>• When weighing yourself on a scale, you position yourself slightly differently each time.<br>• Measuring wind velocity depends on the height and time at which a measurement is taken. Multiple readings must be taken and averaged because gusts and changes in direction affect the value. |

### Random Error vs. Systematic Error

- Systematic error always affects measurements the same amount or by the same proportion, provided that a reading is taken the same way each time. It is predictable.
- Random error causes one measurement to differ slightly from the next. It comes from unpredictable changes during an experiment.
- Random errors cannot be eliminated from an experiment, but most systematic errors may be reduced.

## 6 Physical properties of materials

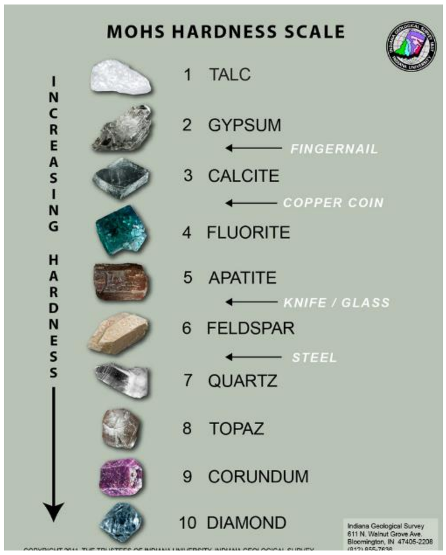
- **Physical property** of a substance is a characteristic that can be observed without causing any permanent change to an object.
- Materials can also be classified based on their physical properties.
- Common properties:
    1. **Strength**: ability to support a heavy load without breaking or tearing.
    2. **Hardness**: ability to scratch another material.
    3. **Density**: amount of mass present in per unit volume of a substance.
    4. **Melting point**: The temperature at which a substance changes from a solid to a liquid.
    5. **Boiling point**: The temperature at which a substance changes from a liquid to a gas.
    6. **Electrical conductivity**: Measures how easily electricity can pass through a substance.
    7. **Thermal conductivity**: Measures how easily heat can pass through a substance
    8. **Flexibility**: Ability to bend without breaking, and to return to its original shape.
    9. **Malleability**: Ability to be beaten into shapes.
    10. **Ductility**: Able to be stretched into wires.

### Hardness: Mohs Hardness Scale

A mineral's **hardness** is a measure of its relative resistance to scratching.

This is measured by scratching the mineral against another substance of known **hardness** on the **Mohs Hardness Scale**.

A harder material will be able to scratch a softer material. A softer material is not able to scratch a harder material.




From the Mohs Hardness Scale, I can conclude that:

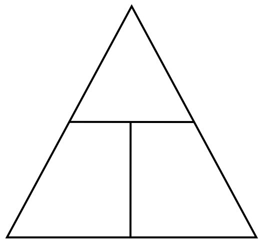
- Apatite is harder than Fluorite, thus Apatite is …………………… Fluorite.
- Diamond is the hardest and thus it is able to scratch all the other materials.

## 7 Density

### (a) What is density?

- Density is the amount of mass present in per unit volume of a substance.
- SI unit: $kg/m^3$
- Other units: $g/cm^3$ (more common)
- Formula:

$$\boxed{\text{Density} = \frac{\text{mass}}{\text{volume}}}$$



**Example 1:**
Calculate the volume of a wooden block (density = $0.6\ g/cm^3$) that has a mass of 600 g.

**Example 2:**
Calculate the mass of an iron nail (density = $7.9\ g/cm^3$) that has a volume of $1.3\ cm^3$.

**Example 3:**
Substance **X** has a shape of a sphere. Calculate the density of substance **X** given that it has a mass of 35 g and radius of 1.5 cm.

## (b) Floating and sinking

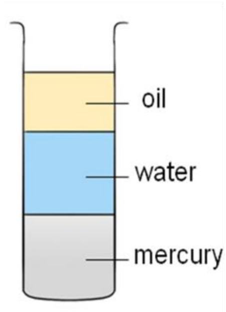
- Objects made of the same substances have the same density.
- The ability of an object to float or sink in a liquid depends on the densities of the object and the liquid.
    - Less dense objects **float** on denser liquids.
    - Denser objects **sink** in less dense liquids.

**Densities of some common substances**

| Substance | Density / $g/cm^3$ |
|---|---|
| Air | 0.00129 |
| Alcohol | 0.79 |
| Petrol | 0.80 |
| Pure water | 1.00 |
| Aluminium | 2.7 |
| Gold | 19.3 |

**Example 4:**

The diagram shows three different liquids (oil, water and mercury) poured into a boiling tube.

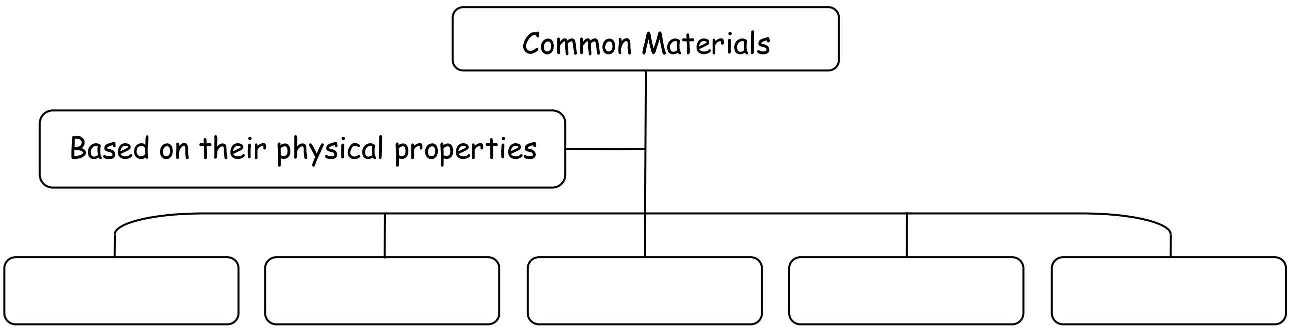



Arrange the liquids in ascending order of density:

……………………………………………………………………..

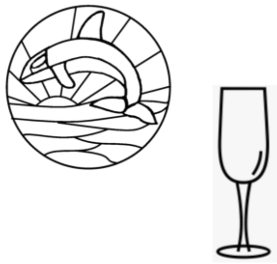
## 8 Materials and Classification of Materials

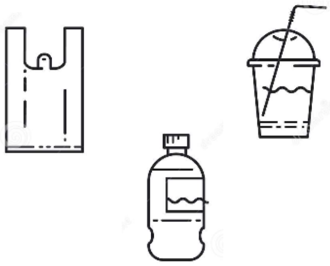
- Material is the substance that is used for making an object.
- Materials can also be classified according to their physical properties.
- Different materials have different physical properties and are classified into 5 main groups.



**(a)** The physical properties of these 5 main groups are listed in the table:

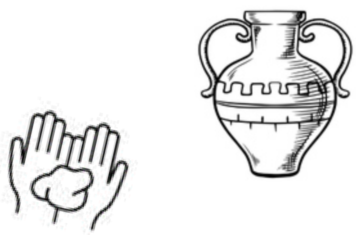
<u>Glass</u>
Source: sand
- Transparent
- Poor conductor of electricity and heat
- Malleable but not ductile
- Very high melting point
- Does not corrode easily
- Fragile / brittle





<u>Plastic</u>
Source: petroleum
- Lightweight
- Poor conductor of electricity and heat
- Malleable and not ductile
- Very low melting point
- Does not corrode easily
- Very strong

<u>Metal</u>
Source: mined from ground
- Shiny and flexible
- Good conductor of electricity and heat
- Malleable and ductile
- Very high melting point
- Flexible and strong
- Some metals corrodes fast, others do not.



<u>Ceramic</u>
Source: clay
- Poor conductor of electricity and heat
- Not malleable or ductile
- Has high melting point
- Does not corrode
- Fragile / brittle

<u>Fibre</u>
Source: cotton (natural) or nylon (man-made)
- Poor conductor of electricity and heat
- Not malleable or ductile
- Has low melting point
- Does not corrode
- Burns easily
- Can be spun into threads and woven into fabrics

**(b)** **Melting point and boiling point** of some common substances:

| Common substance | Melting point / °C | Boiling point / °C |
|---|---|---|
| Oxygen | − 218 | − 183 |
| Alcohol | − 117 | 78 |
| Mercury | − 39 | 357 |
| Pure water | 0 | 100 |
| Copper | 1083 | 2567 |

**(c)** **Electrical conductors and insulators**

- Substances that allow electricity to pass through them easily are good electrical conductors.
- Substances which do not conduct electricity easily are poor electrical conductors or electrical insulators.

| Good conductor | Poor conductor (electrical insulator) |
|---|---|
| Copper<br>Mercury<br>Silver<br>Gold<br>Graphite (pencil lead) | Air<br>Water<br>Wood<br>Plastic<br>Rubber |

**(d)** **Thermal conductors and insulators**

- Substances that allow heat to pass through them easily are good thermal conductors.
- Substances which do not conduct heat easily are poor heat conductors or thermal insulators.

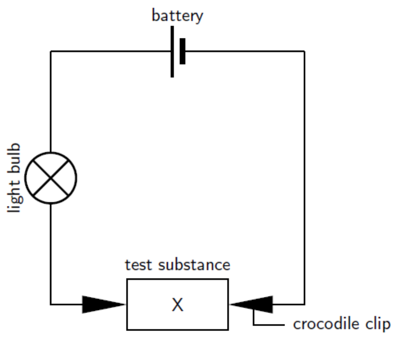
| Good conductor | Poor conductor (thermal insulator) |
|---|---|
| Mercury<br>Aluminium<br>Copper<br>Silver<br>Gold | Air<br>Wood<br>Plastic<br>Glass<br>Ceramics |

**(e)** Criteria for choosing materials

- Different materials have different properties with different strengths and limitations for specific uses.
- Some materials are more suitable than others to make an object for a particular purpose or use.
- The ***criteria*** for choosing a particular material to make an object refers to the **physical properties** that an object must have for it to be useful.

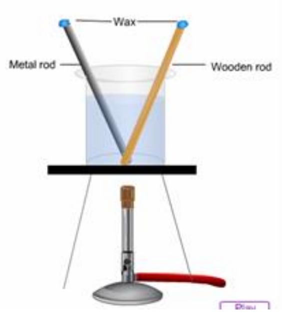
| **Materials** | **Uses** | **Reasons for selecting Material** |
|---|---|---|
| Metals | Aluminim drinking can | • Strong<br>• Low density<br>• Does not corrode easily |
| | Copper electrical wires | • Good conductor of electricity<br>• Strong<br>• Does not corrode |
| | Gold bangles | • Shiny<br>• Does not corrode |
| Plastics | Plastic bags | • Lightweight (low density)<br>• Flexible<br>• Strong |
| | Plastic cups and containers | • Lightweight<br>• Easily moulded<br>• Heat insulator (retains heat) |
| | Plastic switches | • Strong<br>• Electrical insulator |
| Glass | Glass window planes | • Transparent<br>• Hard |
| | Thin protective glass layer | • Hard<br>• Does not corrode |
| Ceramics | Porcelain plates | • Heat insulator (plate retains heat) |
| | Cooking pots | • Heat insulator (pot retains heat)<br>• Does not corrode<br>• High melting point |
| Fibres | Cotton clothing | • Lightweight<br>• Absorb body perspiration<br>• Able to absorb dyes |
| | Nylon fishing wire | • Strong<br>• Flexible |

**(f) Experiments used to investigate physical properties**




Investigating electrical properties

- Set-up an open circuit, leaving two ends open.
- Connect open ends to the material of investigation.
- A conductor will light up the bulb but an insulator will not.




Investigating thermal properties

- Set-up a beaker of water over a Bunsen burner.
- Place the material of investigation into the water and wax on the tip of the material.
- A conductor will melt the wax, an insulator will not.

**(g) Conservation of materials**

- **Why do we need to conserve materials?**
  - The Earth has a limited amount of materials, which can be depleted one day
  - Some of the discarded materials are 'non-biodegradable' (i.e., cannot be broken down by bacteria) and cause pollution.
  - Rubbish that are incinerated often cause air pollution.

- **How do we conserve materials?**
  - Reduce: use less
    e.g. use both sides of paper, use own shopping bag instead of plastic bags provided by shops
  - Reuse: use old things again instead of throwing them away
  - Recycle: Use old things to make new things
  - Glass, metals, and some plastics can be recycled by melting them down to be made into new products

**Essential Takeaways**

1. Diversity of physical properties in resources is important for the living things to perform different functions.
2. Human have to use these natural resources responsibly and sustainably to avoid the depletion of resources and minimise pollution to the environment.
3. Physical properties of matter help us to understand the complexity of our natural world by studying it in a systematic manner.