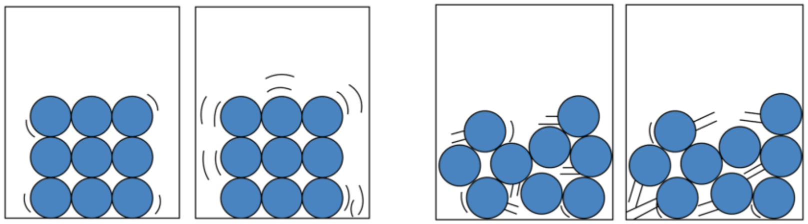
8.01: Heating and Cooling

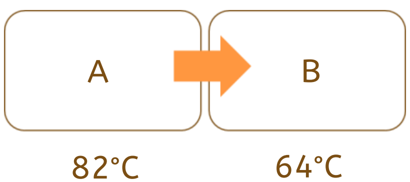
Temperature



- a physical quantity which is a measure of the **average energy** of particles due to their **motion**

Changing Temperature

- Heating and cooling affect an object's **thermal store** of energy.



- Net flow of energy is **always** from hotter to colder objects' thermal store.

- A thermal store can be changed by **any energy pathway** depending on the mechanism causing it.

'Mixing' Objects

same masses

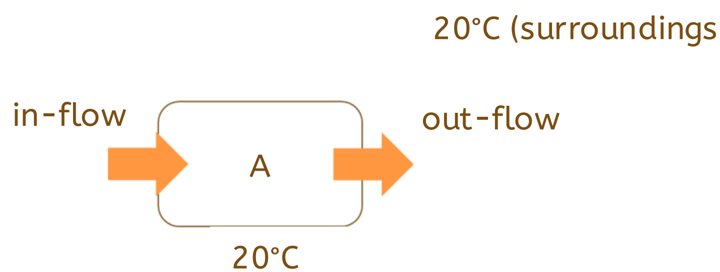
Resulting temperature: halfway between initial temperatures.

different masses

Resulting temperature: between initial temperatures and closer to that of larger mass.

Thermal Equilibrium

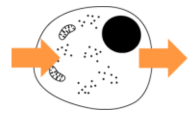
- when two objects reach the **same temperature**
- with no net flow of energy between thermal stores



- Often the result of energy **dissipating** to the cooler surroundings.

8.01: Heating and Cooling

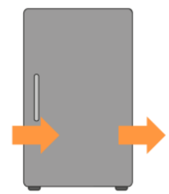
Unchanging Temperature



But not thermal equilibrium (i.e. two objects **not** the same temperature).

higher than surroundings

lower than surroundings

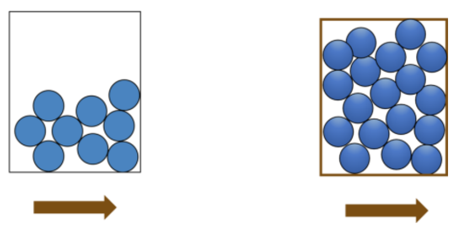


Changing Temperature

For the **same energy** supplied:

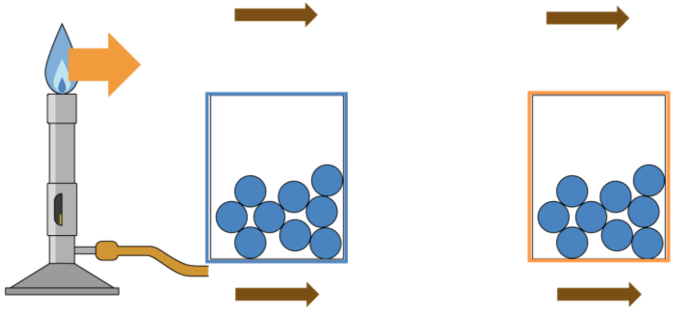
- Greater mass/volume,

→ smaller temperature change.



- Different starting temperature,

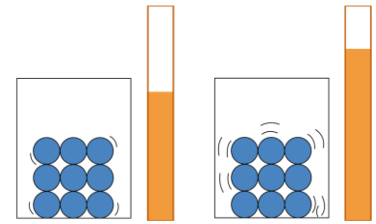
→ same temperature change.



Energy in Thermal Stores

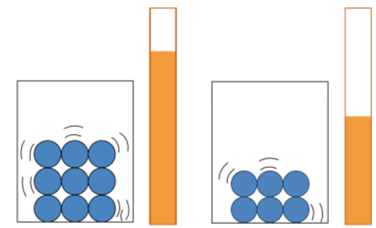
Hotter objects have more energy in their thermal store.

- Particles moving more.
- Each particle has more energy.
- Total energy of all particles: more.



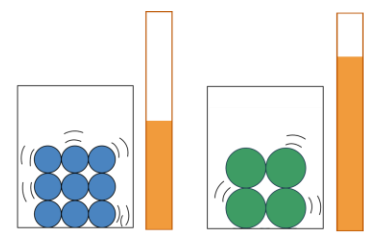
Larger masses have more energy in their thermal store.

- Greater mass: more particles.
- At same temperature, each particle has same energy.
- Total energy of all particles: more.



Some materials have more energy in their thermal store.

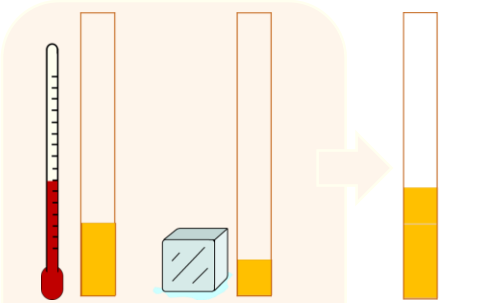
- Some materials have particles that require more energy to vibrate.
- At same temperature, each particle is vibrating the same, but they required more energy to do so.
- Total energy of all particles: more.

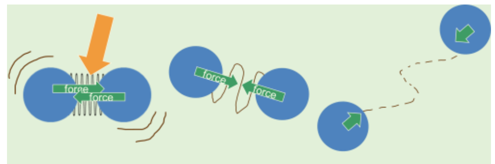


8.01: Heating and Cooling

Internal Energy

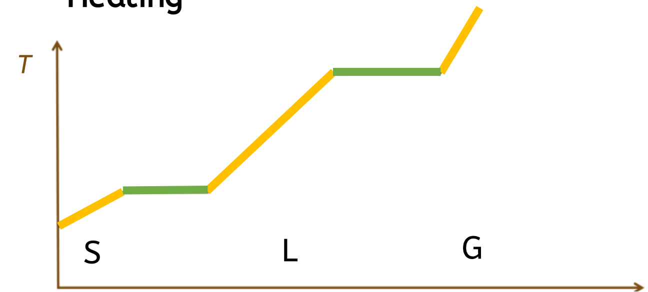
- total energy within an object due to the motion and position of its particles





- *Force* reaches limit for motion.
- More energy in, *Force increases,* ↑.
- Separation increases, ↑ (then stays same).
- *Energy* stored by material.

Heating



- *Temp* changing (no change of state)
- Change of state (no change in *Temp*)

Thermal Transfer

Energy transfers from or to a **thermal store.**

thermal transfer

by **particles**

- **Temperature difference.**
- In contact.

convection — movement of material (fluids)

thermal conduction — no movement of material (solids)

by **waves**

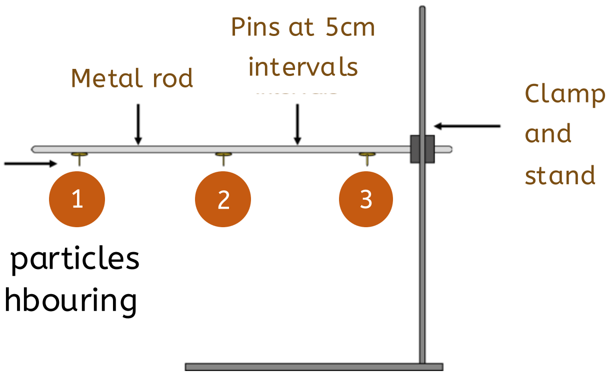
- All objects **'light up' a space** with IR radiation.

thermal radiation

8.01: Heating and Cooling

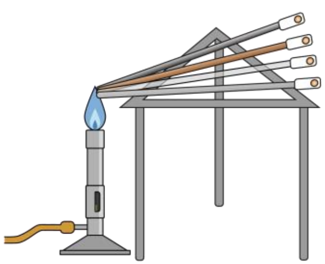
Thermal Conduction

- spontaneous process of energy transfer between a hotter and a cooler object in contact, without the movement of the material



Energy is transferred from particles with lots of energy to neighbouring particles, by vibrations.

Thermal conductivity



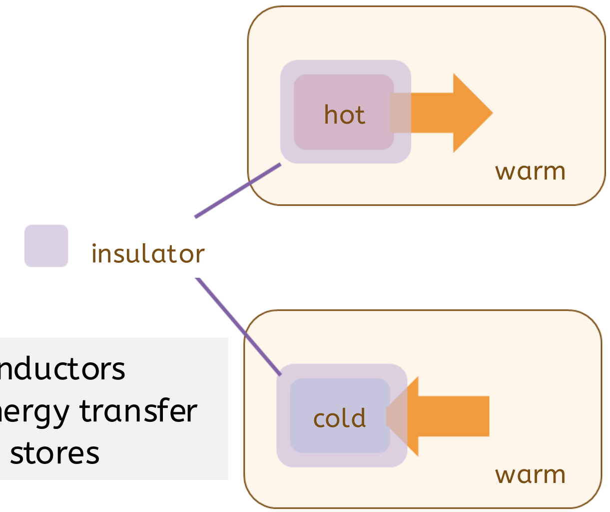
Good conductors have a higher thermal conductivity: energy transmitted easily through them.

Metals are the best thermal conductors.

Rate of thermal conduction

temperature difference	greater	higher rate
material	higher thermal conductivity	
thickness	less thick	
surface area	greater	

Insulators

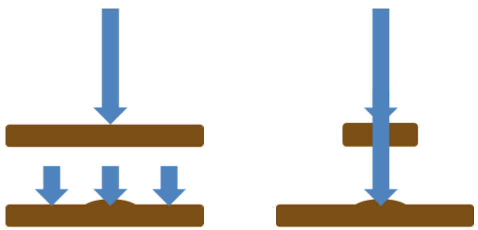


- poor thermal conductors that minimise energy transfer to/from thermal stores

8.01: Heating and Cooling

Pressure

- quantity resulting from a force acting on a surface



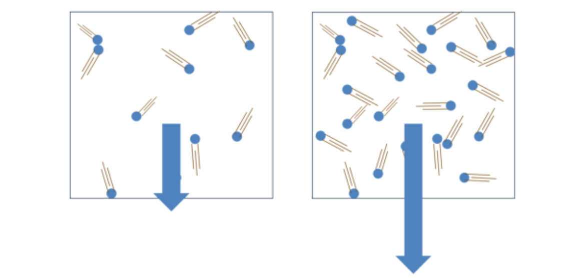
low pressure | high pressure

Pressure on objects

Pressure is **higher** when:

- a force acts over a **smaller surface area**
- a **large force** acts.

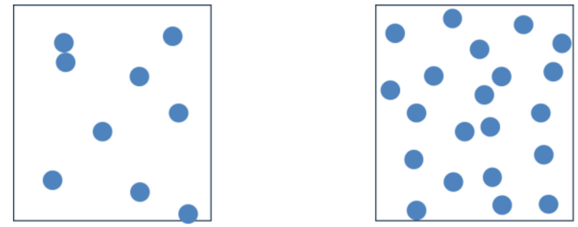
Pressure by a fluid



Forces between particles, and between particles and the inside walls of the container cause pressure on the gas.

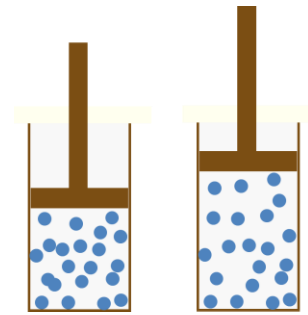
If more particles are causing a higher pressure – greater weight – higher pressure on surface.

Density



low density | high density

Greater mass in the same volume → higher density.

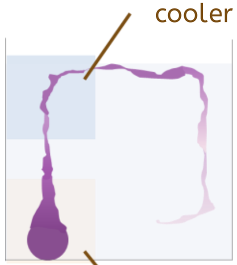


Greater volume of the same mass → lower density.

$$\text{density (g/cm}^3\text{)} = \frac{\text{mass (g)}}{\text{volume (cm}^3\text{)}}$$

8.01: Heating and Cooling

Convection



- movement of a hotter fluid to a colder region

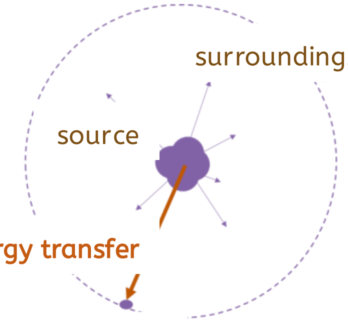
- The less dense region rises.
- The rest of the fluid is more dense.
- The less dense matter 'floats' on more dense matter.

- A region of fluid that is colder sinks to replace the hotter fluid.

- A region of the fluid gets hotter.
- Particles move more.
- The separation between particles increases.
- Fluid expands.
- Its density decreases.

Temperature difference in a fluid causes **convection currents**.

Thermal Radiation

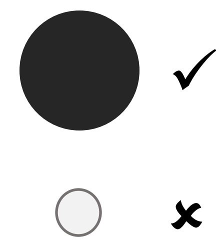


- energy transfer to or from a thermal store by absorption or emission of light
- **no contact** necessary: can be transmitted through a vacuum

- **All** objects emit and absorb infra-red radiation.
- **Hotter** objects emit more energy by IR radiation (more intense).

Surfaces that absorb and emit energy from IR radiation best:

- dark
- matt/rough/dull
- large surface area.



8.01: Heating and Cooling

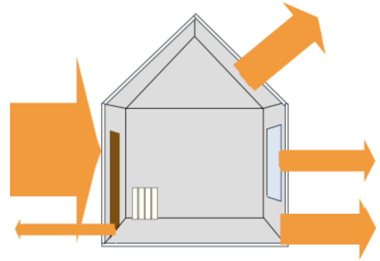
Real-world Contexts

Building Design

To maintain steady temperature independent of surroundings.

The greater the energy supplied, the greater the fuel use and costs.

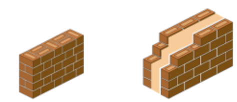
To reduce fuel use:



loft insulation

double glazing

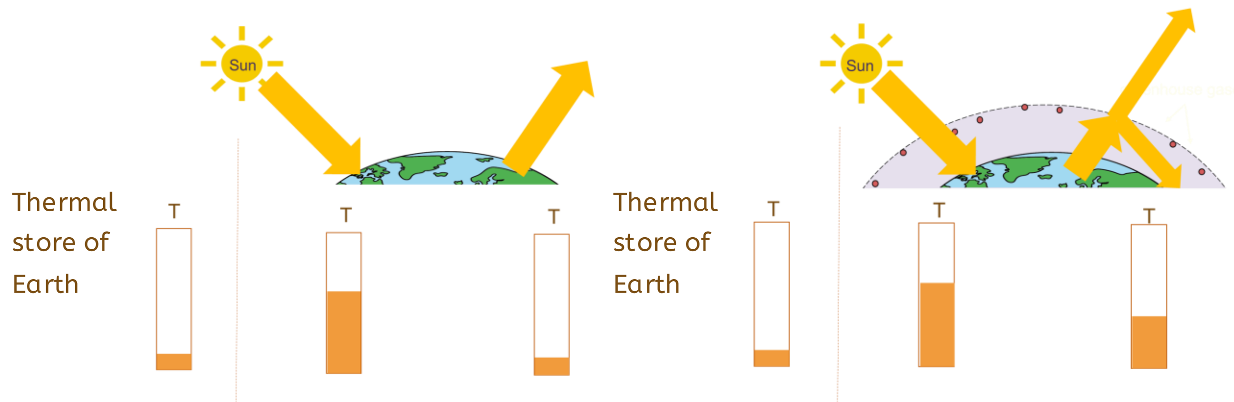
cavity wall insulation



draught excluders

Greenhouse Effect

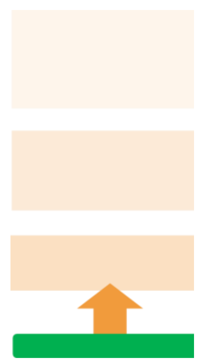
Causes a medium, steady average global temperature.



Weather Systems

Driven by temperature differences of different surfaces of the Earth.

- Low density air exerts less force on Earth's surface: low-pressure.
- Air rises in low-pressure systems.



hotter land/sea

Energy in thermal store of air increases.

Air expands.

Density decreases.

Air rises.

8.01: Heating and cooling

Measurement Error

- the difference between the measured value and the true value of the quantity being measured

Always some uncertainty in measurement

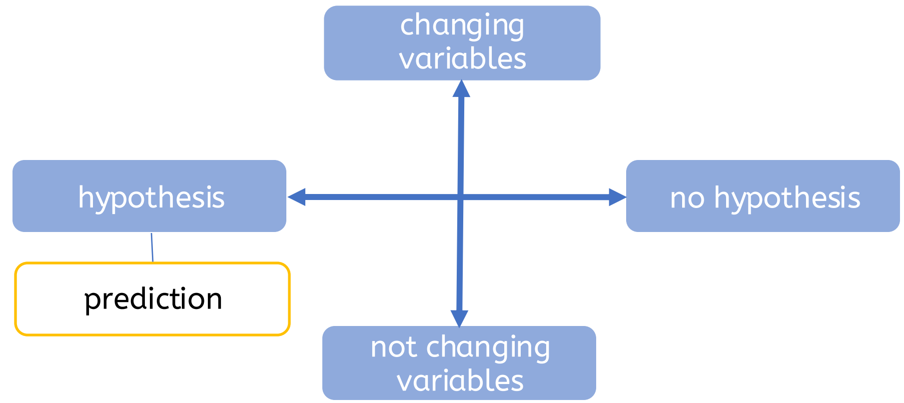
no control over → random error → environmental

- repeat
- mean
- measure over time

some control over → systematic error → method, apparatus, skill

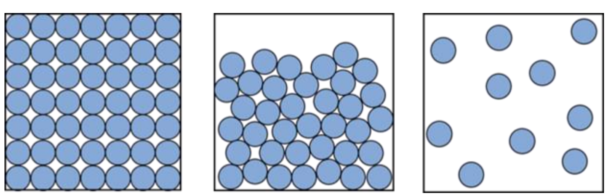
- control/monitor environment
- control procedure/apparatus
- measurement technique

Scientific Methods

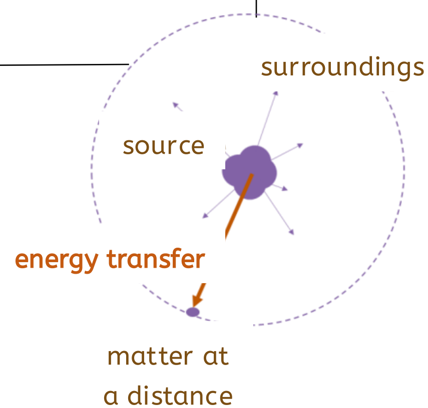


There is not a single way of doing research or a single scientific method.

Using Models

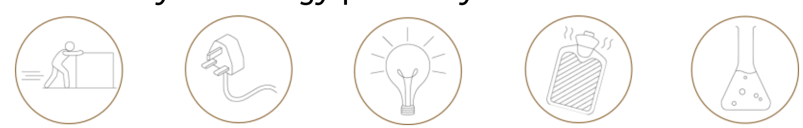


Particle Model



Radiation Model

During events, energy transfers from energy stores by an energy pathway.



Energy Stores and Pathways

8.01: Heating and cooling

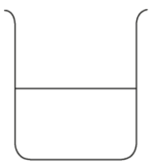
Developing a Method

Line of enquiry → Plan data collection → Type of scientific method → Apparatus / techniques → High-quality data

Plan data collection:
- to answer question
- systematic

Apparatus / techniques:
- resolution
- measurement error
  - impact random error
  - likelihood systematic error

Equipment

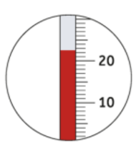
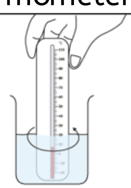
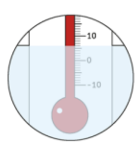
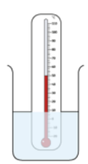
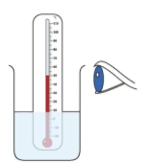


beaker

- Select the appropriate size.
- Place on a flat stable surface.
- Graduated markings: approximate volume.
- Pour in/out liquid carefully.
- After heating, move with tongs or wait to cool.
- If stirring, use a stirrer.

Skilful Techniques

To use a liquid thermometer

				
scale	stir	immersed	stopped	eye level

Safe Practicals

Hazards
All apparatus and techniques

Risks
- harm
- damage

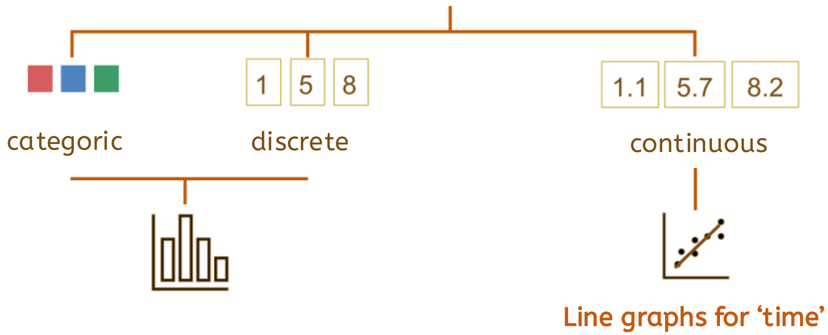
- Follow normal laboratory rules
- Plan and use a risk assessment

Reduced likelihood
- harm
- damage

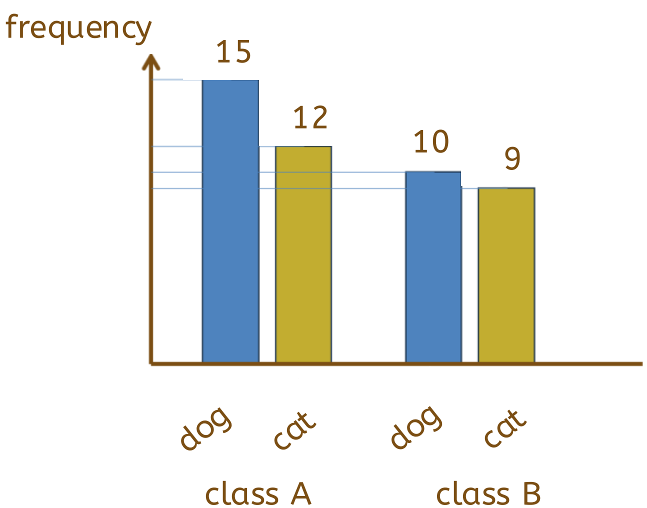
Identify hazards → Judge risk → Plan control measures

8.01: Heating and cooling

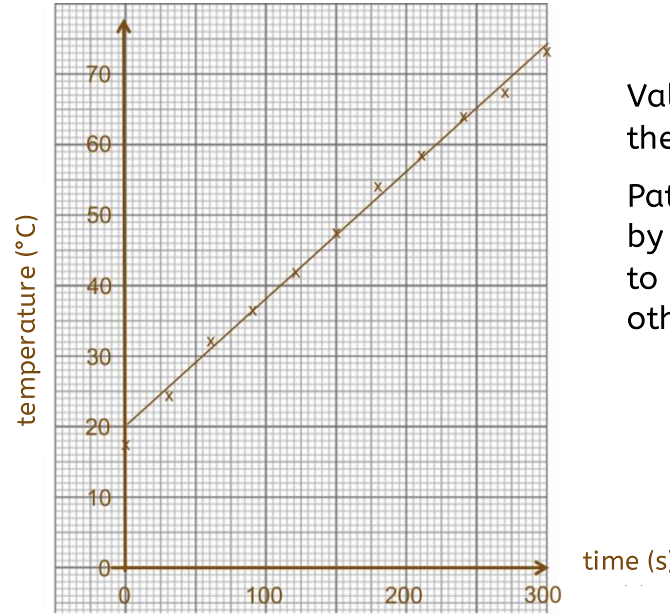
Interpreting Data



Identifying the most appropriate chart or graph depends on the type of data and the line of enquiry:

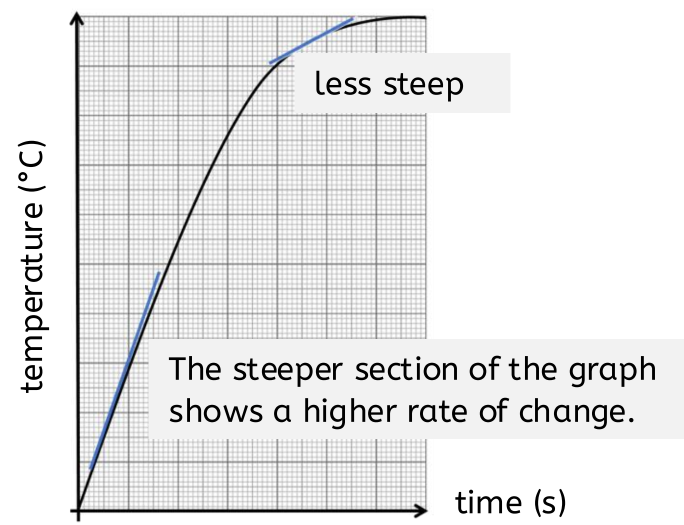


Compound bar charts are useful to compare a variable across different categories.



Values are read off from the best-fit line.

Patterns/trends are found by noticing what happens to one variable when the other is changed.



8.01: Heating and cooling

Making Conclusions

Conclusions

- avoids over-generalisation
- describes pattern
- relates to relevant models
- includes range values
- explains with scientific knowledge

Evaluating Quality of Research

methods

- control of variables
- apparatus

data to answer EQ

- techniques
- skill

measurement error low

data

- range
- systematic intervals
- high resolution

differences can be observed

- low in anomalies
- repeatable
- reproducible

matches multiple datasets

conclusions

- values and patterns logically follow from the data
- conclusions are only based on the collected data
- researcher suggests further research needed

★★★

peer review

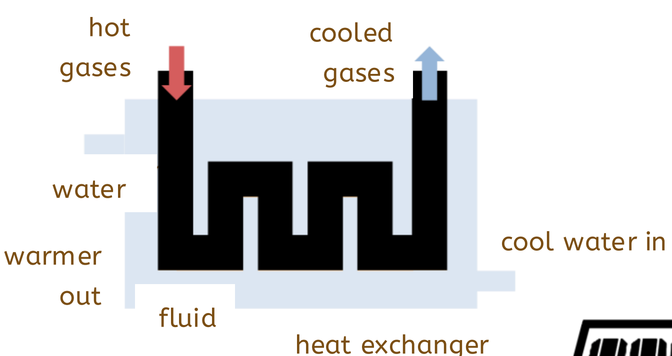
Scientific research is highly valued because of the efforts to produce high-quality data and have it tested by peers.

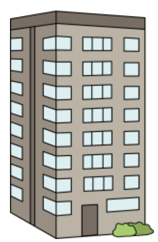
8.01: Heating and cooling

Applications to Industry

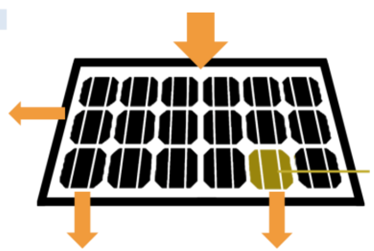
STEM workers

- Design problem needs solving ← Funded by various sources
- Use scientific knowledge to draft designs
- Test designs using modelling
- Select optimal design ← Costs considered

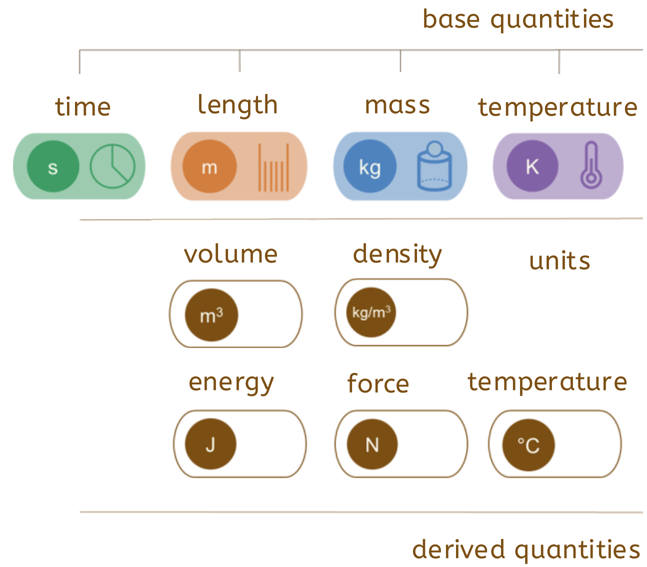




Examples include heat exchanger, building insulation and solar panel glass.



Measurement Values



Quantities and their units:

Base quantities: length, mass, time, temperature (K).

Derived quantities include energy, volume and density and the commonly used temperature unit, °C.

Unit Prefixes:

Range of unit prefixes which differ by the factor of 1000.

Prefixes change numbers to a more human scale.

Easier to compare values that have the same unit prefix.