Density,
Pressure and Change of State
Syllabus points:

5.1 use the following units: degrees Celsius (°C), kelvin (K), joule (J), kilogram (kg), kilogram/metre$^3$ (kg/m$^3$), metre (m), metre$^2$ (m$^2$), metre$^3$ (m$^3$), metre/second (m/s), metre/second$^2$ (m/s$^2$), newton (N), pascal (Pa).

5.2 know and use the relationship between density, mass and volume:

\[ \text{density} = \frac{\text{mass}}{\text{volume}} \quad \rho = \frac{m}{V} \]

5.3 describe experiments to determine density using direct measurements of mass and volume

5.4 know and use the relationship between pressure, force and area:

\[ \text{pressure} = \frac{\text{force}}{\text{area}} \quad p = \frac{F}{A} \]

5.5 understand that the pressure at a point in a gas or liquid which is at rest acts equally in all directions

5.6 know and use the relationship for pressure difference:

\[ \text{Pressure difference} = \text{density} \times g \times \text{height} \quad P = \rho \times g \times h \]

5.7 understand the changes that occur when a solid melts to form a liquid, and when a liquid evaporates or boils to form a gas

5.8 describe the arrangement and motion of particles in solids, liquids and gases
5.1 use the following units: degrees Celsius (°C), kelvin (K), joule (J), kilogram (kg), kilogram/metre³ (kg/m³), metre (m), metre² (m²), metre³ (m³), metre/second (m/s), metre/second² (m/s²), newton (N), pascal (Pa).

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Quantity symbol</th>
<th>Units</th>
<th>Symbol</th>
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<tbody>
<tr>
<td>Temperature</td>
<td>T&lt;sub&gt;c&lt;/sub&gt;</td>
<td>Celsius</td>
<td>°C</td>
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<tr>
<td>Temperature</td>
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<td>Energy</td>
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<td>Joule</td>
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<td>Mass</td>
<td>M</td>
<td>Kilogram</td>
<td>kg</td>
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<td>Density</td>
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<td>kilogram/metre³</td>
<td>kg/m³</td>
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<tr>
<td>Distance</td>
<td>d</td>
<td>metre</td>
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<tr>
<td>Area</td>
<td>A</td>
<td>metre²</td>
<td>m²</td>
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<td>Volume</td>
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<td>metre³</td>
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<tr>
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<tr>
<td>Force</td>
<td>F</td>
<td>newton</td>
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<td>Pressure</td>
<td>P</td>
<td>pascal</td>
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</table>

5.2 know and use the relationship between density, mass and volume:

\[
\text{density} = \frac{\text{mass}}{\text{volume}} \quad \rho = \frac{m}{V}
\]

- If you pack more mass into the same volume, it’s more dense

![High Density](image1.png) ![Low Density](image2.png)
• If you pack the same mass into a smaller volume, it’s more dense

![Low density](image1.png) ![High Density](image2.png)

Remember!

Just because something has more mass doesn't mean it's more dense.

Density is not a measurement of how heavy something is, or a measurement of how big something is – it’s a combination of these two things together. Be careful not to use the words “heavy” or “light” when what you mean is “dense” or “not dense”/“low density”.

Calculating Density

\[
\text{Density} = \frac{\text{mass}}{\text{volume}} \quad \rho = \frac{m}{V}
\]

- The standard unit for mass is the kilogram (kg).
- The standard unit for volume is the metre cubed (m³).
- Therefore the standard unit for density is kilogram per metre cubed (kg/m³).
  - You may also see g/cm³ used quite often. 
  \[1\text{g/cm}^3 = 1000\text{kg/m}^3\]

Make sure when calculating density that you’re working in **kilograms** and **metres cubed**, not grams and/or centimetres cubed.

It is generally easier to convert g →kg and cm→ m before you complete the calculation however, you can find the density in grams per centimetre cubed and then convert to kilograms per metre cubed: 1 g/cm³ = 1000 kg/m³.
5.3 describe experiments to determine density using direct measurements of mass and volume

**Regular Objects (Eg Cube)**

- Find the mass of the solid **using a top-pan balance** in kg
- **Using a ruler** measure the length, width and height of the object in metres
- Find the volume of the solid by multiplying l x w x h
- Use the formula $\rho = \frac{m}{V}$ to find the density

**Irregular Objects (Eg Rocks)**

- Find the mass of the solid **using a top-pan balance** in kg
- Drop an object in water and find it volume by seeing how much water it **DISPLACES** (pushes out of the way). The water which is displaced has the same volume as the object.

![Measuring Cylinder](image1.png) ![Eureka Can](image2.png)

- Use the formula $\rho = \frac{m}{V}$ to find the density

**Key points**

- Always find the mass before placing objects in water
- Use enough water to cover the object but not too much that it overflows
- Be careful not to allow splashes as you place the objects in the water
- If you have more than one identical objects (eg marbles) use multiple marbles to find the mass and volume and find an average before calculating the density → reduces error in readings.
5.4 know and use the relationship between pressure, force and area:

\[ \text{pressure} = \frac{\text{force}}{\text{area}} \quad \text{p}=\frac{F}{A} \]

Pressure is proportional to force
- If you double the force you double the pressure

Pressure is inversely proportional to area
- If you double the area you halve the pressure

\[ \text{Pressure} = \frac{\text{Force}}{\text{Area}} \quad \text{p} = \frac{F}{A} \]

For the same force the pressure will increase if the area is decreased

Low Pressure \hspace{1cm} \text{High Pressure}

For the same area the pressure will increase if the force is increased

Low Pressure \hspace{1cm} \text{High Pressure}

- The standard unit for force is the newton (N).
- The standard unit for area is the metre squared (m\(^2\)).
- Therefore the standard unit for pressure is:
  - newton per metre squared (N/m\(^2\)).
  - Pascal (Pa)

Key points
- Make sure that when you calculate pressure that you are working in newtons and metres squared.
- You cannot calculate pressure using mass, and will need to convert mass to weight (by multiplying by \( g = 10\text{m/s}^2 \)) if the weight is not provided.
- Converting from centimetres squared to metres squared is difficult, so work in metres from the very start.

5.5 understand that the pressure at a point in a gas or liquid which is at rest acts equally in all directions.

At any point in a fluid (liquid or gas) the forces from each direction are equal. This only applies if the fluid isn’t moving (e.g., a static fluid) – watch out for “What assumption did you make?” questions.

5.6 know and use the relationship for pressure difference:

Pressure difference = density \times g \times height \quad P = \rho \times g \times h

The deeper the water the greater the pressure because the weight of the water is greater.

The crab at the bottom of the diagram would have more pressure exerted on it than the fish half way up.

The pressure does not depend on the weight of the object but only the height of the fluid.

- The standard unit for density is the kilogram per metre cubed (kg/m³).
- The standard unit for height is the metre (m).
- Therefore the standard unit for Pressure is the Pascal (Pa).
Key points

- Remember that \( g = 10 \text{m/s}^2 \)

For 5.7, understand the changes that occur when a solid melts to form a liquid, and when a liquid evaporates or boils to form a gas.

- When a solid is heated and melts into a liquid, the bonds between particles are weakened and the arrangement of the particles becomes more irregular and disordered.

- When a liquid is heated and boils into a gas the bonds are broken (i.e. they disappear) and the particles are completely free to move about.

- When substances are cooled the opposite processes happen.

If energy is added (e.g. increasing the temperature or increasing pressure) or if energy is taken away (e.g. freezing something or decreasing pressure) you have created a **physical change**.

The plateau (flat parts) of the graph where the temperature of the substance is not increasing occurs due to the energy making/breaking bonds between the particles. Once the state change is complete then the energy goes into raising the temperature of the substance.
5.8 describe the arrangement and motion of particles in solids, liquids and gases

**Solid**

- Close-packed
- Regular arrangement
- Strong bonds
- Particles vibrate

**Liquid**

- Close-packed
- Irregular arrangement
- Weak forces between particles
- Random motion

**Gas**

- Large gaps between particles
- Irregular arrangement
- No forces between particles
- Free to move