On Earth, the three most common states, or phases, of matter are solid, liquid, and gas.

This table describes the differences between them:

| | Solid | Fluid | |
		Liquid	Gas
Fixed Shape?	Yes	No	No
Fixed Volume?	Yes	Yes	No
Distance between particles	Small	Almost as Small as a Solid	Large
Force of attraction between particles	Large	Medium	Small
Kinetic Energy of Particles	Small	Medium	Large
Example: H_2O	Ice	Water	Water Vapor

Flipping Physics Lecture Notes:
Density
http://www.flippingphysics.com/density.html

Density is a material property of any pure substance. For example, the density of pure copper is 8.96 g/cm³. And, any object made of pure copper, regardless of size, will have that same density of 8.96 g/cm³.

The symbol for density is ρ. Which is the lowercase, Greek letter "rho".

The equation for density is: $\rho = \dfrac{\text{mass}}{\text{volume}}$

Let's determine the densities of two, equal diameter spheres. One steel and one wood:

$$\text{diameter} = 50.7mm \Rightarrow r = \frac{\text{diameter}}{2} = \frac{50.7mm}{2} = 25.35mm\left(\frac{1cm}{10mm}\right) = 2.535cm$$

$$V_{\text{sphere}} = \frac{4}{3}\pi r^3 = \frac{4}{3}\pi(2.535cm)^3 = 68.2374cm^3 = V_{\text{steel}} = V_{\text{wood}}$$

$$m_{\text{wood}} = ??g \,\&\, m_{\text{steel}} = 535g$$

$$\rho_{\text{steel}} = \frac{m_{\text{steel}}}{V_{\text{steel}}} = \frac{535g}{68.2374cm^3} = 7.84027 \Rightarrow \rho_{\text{steel}} \approx 7.84\frac{g}{cm^3} \text{ (observed value)}$$

$$\rho_{\text{wood}} = \frac{m_{\text{wood}}}{V_{\text{wood}}} = \frac{45g}{68.2374cm^3} = 0.65946 \Rightarrow \rho_{\text{wood}} \approx 0.66\frac{g}{cm^3} \text{ (observed value)}$$

The accepted value for the density of steel is roughly 7.7 – 8.0 g/cm³.[♥]
The accepted value for the density of birch wood is roughly 0.5 – 0.8 g/cm³.[♣]
So, both of our observed values are within the range of their accepted values.

We have just shown that steel is more dense than wood, and steel has a larger mass per unit volume than wood.

[♥] https://hypertextbook.com/facts/2004/KarenSutherland.shtml
[♣] https://www.engineeringtoolbox.com/wood-density-d_40.html

If you pound a hammer against a nail with the nail oriented with the flat head of the nail against a wood board, the nail will not pierce the wood board. The reason why has to do with pressure!

Pressure equals Force over Area: Pressure, $P = \dfrac{F}{A}$

Example: You can determine the pressure caused by your feet pressing against the ground. For me the numbers are:

The area of one foot is roughly a 21 cm by 7.0 cm rectangle:
$A_{\text{foot}} = 21cm \times 7.0cm \approx 147cm^2$
However, let's have all our numbers in base S.I. units. So, let's convert to square meters.
$A_{\text{foot}} = 147cm^2 \times \dfrac{1^2 m^2}{100^2 cm^2} = 0.0147m^2 \Rightarrow A_{2\text{ feet}} = 2 \times 0.0147 = 0.0294m^2$
And I actually have two feet, not just one.

The weight of my body in newtons: weight $= 170\text{pounds} \times \dfrac{4.448N}{1\text{pound}} = 756.16N = F_g$

And we can determine the pressure on my two feet caused by the weight of my body while I am standing at rest.
$P_{2\text{ feet}} = \dfrac{F_g}{A_{2\text{ feet}}} = \dfrac{756.16}{0.0294} = 25720\dfrac{N}{m^2} = 25720Pa \times \dfrac{1kPa}{1000Pa} \approx 26kPa$
Note: Pressure is measured in newtons per square meter and those are called pascals in honor of Blaise Pascal, a 17th century French physicist, mathematician, and inventor.

- Pascal, $1\,Pa = 1\dfrac{N}{m^2}$

Also, pressure is often measured in kilopascals, kPa, just like kilometers and kilograms.

$P_{1\text{ foot}} = \dfrac{F_g}{A_{2\text{ feet}}/2} = (2)\dfrac{F_g}{A_{2\text{ feet}}} = (2)P_{2\text{ feet}} = (2)(25720) = 51440\dfrac{N}{m^2} \approx 51kPa$

And going back to the nail example, if you turn the nail around so the pointy side is on the wood board, the area in contact with the wood board is significantly decreased, which means, using the same force from the hammer, the pressure from the nail on the wood board is significantly increased, and the nail will pierce the wood board!

A few additional tidbits:
- The equation definition for pressure actually has the force perpendicular to the surface in it, not just the force. Any force component of the force which is parallel to the surface does not cause any pressure on the surface. $P \equiv \dfrac{F_\perp}{A}$
- Pressure is a scalar. Pressure does not have direction, it has only magnitude.

Example: We can determine the pressure exerted by water in a rectangular fish tank on the bottom of the tank. For this tadpole tank, our numbers are:

The area of the bottom of the tank in square meters:

$$A_{\text{bottom}} = 50.2cm \times 25.4cm = 1275cm^2 \times \frac{1^2 m^2}{100^2 cm^2} = 0.1275cm^2$$

The height (or depth) of the water in meters:

$$h_{\text{water}} = 18.5cm \times \frac{1m}{100cm} = 0.185m$$

And we can solve for the pressure on the bottom of the tadpole tank caused by the weight of the water pushing down on the bottom of the tank:

$$P_{\text{bottom}} = \frac{F_g}{A_{\text{bottom}}} \ \& \ F_g = mg$$

We need to determine the weight, or force of gravity, of the water.
For that we need to use the density equation:

$$\rho = \frac{m}{V} \Rightarrow m = \rho V = \rho Ah \Rightarrow F_g = mg = \rho A_{\text{bottom}} hg$$

And we can substitute that back into our pressure equation:

$$P_{\text{bottom}} = \frac{F_g}{A_{\text{bottom}}} = \frac{\rho A_{\text{bottom}} hg}{A_{\text{bottom}}} \Rightarrow P_{\text{bottom}} = \rho gh$$

Which means we need the density of water at room temperature:

$$\rho_{\text{water}} = 998 \frac{kg}{m^3}$$

We can solve for the pressure caused by the water on the bottom of the tadpole tank:

$$\Rightarrow P_{\text{bottom}} = \rho gh = (998)(9.81)(0.185) = 1793Pa \times \frac{1kPa}{1000Pa} \approx 1.79kPa$$

Notice the area of the tank cancelled out of the equation. In other words, the pressure caused by a fluid, $P_{\text{fluid}} = \rho gh$, depends on:
- ρ, the density of the fluid.
- g, the gravitational field of the planet.
- h, the depth of the fluid.
  - *It does **not** depend on the area of the fluid*

In other words, the deeper you dive into water, the larger the pressure from the water. The weight of all the water above you pushes down on you causing this pressure.

The same is true for all the air in the atmosphere above you. This is why there is pressure all around you when you are standing on the surface of the Earth. The miles and miles of air above you is pushing down and causing the pressure you currently experience.[♥] This is called atmospheric pressure and is a typical unit.

- $1.00 atm = 1.01 \times 10^5 Pa$.
  - In other words, 1 atmospheres of pressure is 1.01 x 10⁵ Pa.
- This is the pressure referred to in Standard Temperature and Pressure or STP.
  - Standard Pressure is 1.00 atm.
  - Standard Temperature is 0°C or 32°F or 273.15 Kelvins.

This atmospheric pressure is pushing down on the tank of water. That means the total pressure at the bottom of the tank is the addition of the atmospheric pressure and the pressure caused by the water.

- $P_{total} = P_{atm} + \rho g h$
- The pressure caused by a vertical column of fluid is called *gauge* pressure.
  - $P_{gauge} = \rho g h$
- The total pressure is called the *absolute* pressure.
  - $P_{absolute} = P_{atm} + P_{gauge}$
- The absolute pressure at the bottom of the tank is:
  - $P_{absolute} = P_{atm} + P_{gauge} = 1.01 \times 10^5 + 1793 = 102793 Pa \times \frac{1kPa}{1000Pa} \approx 103 kPa$

A few extra tidbits:
- What we've been talking about here is called Fluid Pressure. The pressure from the water and the air on objects is fluid pressure.
- The particles in fluids are constantly moving around, colliding with one another, and colliding with the surface bordering the fluid. The pressure exerted by a fluid is caused by the particles in the fluid colliding with the surfaces next to the fluid.
- Often liquids are considered to be incompressible. The volumes and densities of incompressible fluids do not change regardless of the pressure applied to them.

[♥] Yes, I am assuming you are reading this while on the surface of planet Earth and not underwater.