*Physics > Big idea PMA: Matter > Topic PMA2: Floating and sinking*

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| **Key concept (age 11-14)** |
| **PMA2.2: Pressure in fluids** |

**What’s the big idea?**

A big idea in physics is matter. Matter is a more formal word for ‘stuff’. Anything that can be stored in a container, or weighed, is matter. Scientific ideas can help to explain why a given material behaves as it does, and may help scientists to develop new materials with specific properties.

**How does this key concept develop understanding of the big idea?**

This key concept helps to develop the big idea by building on the kinetic particle model, to develop general rules for pressure in a fluid, which in turn explain what causes buoyancy.

****The conceptual progression starts by checking understanding of the motion of particles in liquids and gases. It then supports the development of an understanding of what causes pressure in fluids, and of how changes of depth cause changes in pressure, in order to explain buoyancy.

**Using the progression toolkit to support student learning**

Use diagnostic questions to identify quickly where your students are in their conceptual progression. Then decide how to best focus and sequence your teaching. Use further diagnostic questions and response activities to move student understanding forwards.

**Progression toolkit: Pressure in fluids**

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| **Learning focus** | Pressure increases with depth in a fluid, so the force exerted by a fluid is larger on the lower surface of an immersed object than on the upper surface. This results in an upward force on the object. | | | | |
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| **As students’ conceptual understanding progresses they can:** | **C o n c e p t u a l p r o g r e s s I o n** | | | | |
| Describe the movement of particles in fluids on either side of a boundary.  **P** | Explain phenomena that are caused by differences in fluid pressure, on either side of a boundary. | Explain why pressure in a fluid increases with depth. | Explain why pressure at a particular depth is the same throughout a fluid. | Explain how pressure pushes on an object submerged in a fluid. |
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| **Diagnostic questions** | Inflation | Magic glass | Underwater beach ball | Deep water | Underwater basketball |
| Squeezing water | Underwater cave |
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| **Response**  **activities** |  | Pressure can | Diving deep | | |

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| Key: | | | |
| **P** | Prior understanding from earlier stages of learning |  |  |

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| **Inflation** | **Magic glass** | **Underwater beach ball** | **Squeezing water** | **Deep water** |
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| Confidence grid and  simple multiple choice | Confidence grid | Confidence grid | Simple multiple choice | Simple multiple choice |
| **Underwater cave** | **Underwater basketball** | **Pressure can** | **Diving deep** |  |
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| Two-tier multiple choice | Linking ideas | Predict, explain; observe, explain (PEOE) | Talking heads |  |

**What’s the science story?**

A fluid is a liquid or a gas.

An object immersed in a fluid experiences forces acting on its surfaces caused by the pressure of the fluid. At any given point in a fluid, pressure acts equally in all directions. Its size is equal to the force acting normal to a surface, divided by the surface area (pressure = force divided by area).

The pressure at a point in a fluid is proportional to its depth, as it is caused by the gravitational force on the fluid above that point.

The pressure of the Earth’s atmosphere is called atmospheric pressure. Usually atmospheric pressure causes equal forces to act in all directions on objects, so its presence is not apparent. But if a vacuum, or partial vacuum, is created by removing air, the force due to atmospheric pressure can cause movement (e.g. liquid moving up a drinking straw) or other effects (such as rubber suckers being pressed tightly on to surfaces).

Because pressure is proportional to depth in a fluid, the force exerted by a fluid is larger on the lower surface of an immersed object than on the upper surface. This difference causes the observed upthrust. It also explains why the apparent weight of a fully or partly immersed object is less than its weight out of the fluid.

All of these ideas apply to objects immersed in a gas (such as air) though the size of the upthrust is much smaller than for a liquid.

**What does the research say?**

In his paper on the progression in children’s understanding of basic particle theory, Johnson (1998) summarises findings from previous research. Children’s understanding of particles in liquids and gases revealed several misunderstandings that included:

1. Intrinsic motion of particles – Students showed very little appreciation of the movement of particles.
2. The ‘space’ between the particles – The idea that there is ‘nothing’ between particles, even in the gas state, caused difficulties for many students.
3. The nature of the particles – Many students gave macroscopic properties to the particles, seeing them as a fragmentation of the substance as a whole.

Both Séré, in her study (n=600) of what 11- to 13-year-olds thought about gases ( Séré, 1986), and Besson, in his study (n=944) of upper secondary and university students’ conceptions and reasoning about fluids (Besson, 2004), argue that there is a need for students to systematically reason how the motion of particles cause pressure effects, as a preliminary to the study of pressure, in order to avoid several common misunderstandings.

For students to develop a robust understanding of pressure in fluids, Psillos (1999) suggests that they first observe and describe phenomena caused by fluid pressure, before using ideas about the movement of particles to explain the cause of each one. He also recommends that the equation P=F/A should be left until near the end of the learning progression, to describe the relationship between the variables, and not as a definition of pressure. Many students confuse force and pressure, and introducing the equation before they have a clear understanding of pressure is likely to be counterproductive.

Students generally understand increases in pressure, such as when a tyre is inflated, and make links between the amount of a gas squashed into a container and its pressure ( Séré, 1985; Besson, 2004). Some however, consider that there is a *normal amount* of air that if exceeded, causes pressure; and if it is not exceeded, there is *no* pressure ( Séré, 1985). Students find explanations involving reduced pressure or equilibria more challenging. For example, in a study by Engel Clough and Driver (1985), about half of students aged 11-13 (n=84) described vacuums as actively sucking.

Students often think that fluids can only exert a pressure when they are moving, and assume that the pressure is in the direction of motion ( Séré, 1986; Driver et al., 1994).

Engel Clough and Driver (1985) found that 67% of 12-year-olds, 80% of 14-year-olds and 87% of 16-year-olds (n=84) realised that pressure increases with depth in a liquid. However, only 13% of 12-year-olds, increasing to 34% of 16-year-olds recognised that pressure in the liquid acts in all directions. It is common for students to have the misunderstandings: that pressure *is the weight of the liquid;* and that pressure in a liquid pushes only downwards.

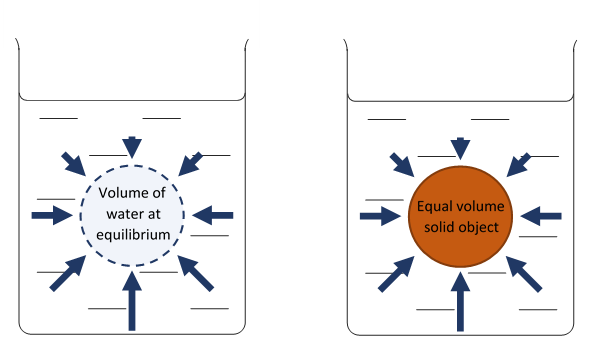
The misunderstanding that pressure at a depth in a liquid is equal to the weight of liquid above that point ignores the atmospheric pressure of the air on the surface. For example, the pressure at a one metre depth in water, is about eleven times the water’s weight (Besson, 2004).

It is common for students to think that pressure is bigger at the bottom of a wider container, than at the same depth in a narrower one, because the total weight of the liquid it contains is greater (Engel Clough and Driver, 1985; Psillos, 1999; Besson, 2004). Besson (2004) found that just 14% of students aged 14-18 (n=141) predicted correctly that pressure depended *only* on depth, in a particular liquid. He found that 60% of students thought pressure was larger in a wider container; and surprisingly, that 20% thought pressure was bigger in a narrower one. One common justification for the latter misunderstanding was that a fluid in a smaller space is more tightly packed, and another is that the walls of a container actively press in on the fluid.

Besson (2004) asked students to predict how pressure in an underwater cave compared to pressure at the same depth in open water. He found that 8% of 14- to 15-year-olds (n=96) thought the pressure would be the same in each case; 56% thought pressure would be greater in the cave; and 36% that pressure would be greater in open water. In follow up to this question, he asked students how they thought their predicted differences in pressure would affect the flow of water into or out of the cave. This prompted many of them to reassess their thinking towards a more scientific understanding.

Even though most students understand that pressure increases with depth in a liquid, many are not sure about *how* pressure can increase with depth. This is because they understand liquids to be incompressible. Just 12% of 14- to 18-year-olds (n= 120) attribute increased pressure in a liquid to a change in the separation of its particles (Besson, 2004). In reality liquids can be compressed by tiny fractions, and are compressed more closely together as depth increases.

**Guidance notes**

Pressure of water on a boat is the same as the pressure needed to support the water that would fill the same space, if the boat were not there. This pressure increases with depth, and results in a net upwards force on the boat.

When a ‘ball of water’ is suspended in water the differences in pressure produce a resultant upward force on the ‘ball of water’ which exactly equals its weight. If the ‘ball of water’ is swapped for a solid ball, exactly the same pressure differences remain and the upwards force is the same – which is equal to the weight of the water that the solid ball has replaced (Nave).

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