*Physics > Big idea PMA: Matter > Topic PMA4: Particle explanations*

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| **Key concept (age 14-16)** |
| **PMA4.2: Pressure** |

**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 exploring what is really meant by pressure and by using the particle model to explain the connection between the pressure of a fluid and the force it exerts on a surface.

The conceptual progression starts by checking knowledge of the factors that can change the pressure of a gas. The particle model is then used to develop an understanding of what causes the pressure that a liquid or a gas has, enabling an understanding of the distinction between pressure and force, and leading to a formal equation that describes the relationship between them.

**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**

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| **Learning focus** | The pressure of a fluid is a measure of how hard its particles are pushing each other apart, and it is proportional to the size of the force exerted by the fluid on a surface. | | | | |
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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** | | | | |
| Identify factors that can increase the pressure of a fluid.  **P** | Explain why the pressure of a fluid is a scalar quantity that is equal in all directions. | Explain the effect of temperature change on the pressure of a fixed volume of fluid. | Distinguish between pressure and force. | Interpret the equation  F = P x A. |
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| **Diagnostic questions** | Increasing the pressure | Squashing air | Hot air | Doubling up | Force and pressure |
| More pressure | Cold air |
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| **Response**  **activities** |  | Gas pressure | | Big fish, little fish |  |
| Bottled gas | |

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

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| **Increasing the pressure** | **Squashing air** | **More pressure** | **Hot air** | **Cold air** |
|  |  |  |  |  |
| Simple multiple choice | Confidence grid | Simple multiple choice | Simple multiple choice | Confidence grid |
| **Doubling up** | **Force and pressure** | **Gas pressure** | **Bottled gas** | **Big fish, little fish** |
|  |  |  |  |  |
| Simple multiple choice | Two-tier multiple choice | Explanation story | Application and practice | Talking heads |

**What’s the science story?**

Increasing the temperature of a gas will increase the average speed of its particles. If it is in a container that has a fixed volume, the particles will hit each other both at a higher speed and more frequently. This will increase both the pressure of the gas and the force that the gas exerts on the walls of the container.

Squeezing a gas into a smaller volume will increase the number of particles in each cubic centimetre of the gas. The particles will hit each other more frequently. This will increase the pressure of the gas. If the gas is in a container, more particles will hit each square centimetre of its walls each second. This will increase the force of the gas on each square centimetre of the walls of the container.

**Earlier development of understanding (BEST 11-14)**

When applying their understanding to novel situations, students of all ages often revert to earlier misunderstandings. Before moving forward it is worthwhile using diagnostic questions to check that students do not have any persistent blocks on their learning. Time spent consolidating the scientific understanding of earlier concepts before moving forward can accelerate progression later.

**Key concept: CPS1.1 Particles model for the solid, liquid and gas states**

Learning focus: The particle model of matter can explain the properties of substances in the solid, liquid and gas states.

This key concept:

* Consolidates understanding of the solid, liquid and gas states through observable properties.
* Develops understanding of the arrangement and movement of particles in each state of matter.
* Uses understanding of the particle model to explain the properties of substances in the solid, liquid and gas states and to explain changes of state.

**Key concept: PMA2.2 Pressure in fluids**

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.

This key concept:

* Consolidates understanding of the movement of particles on either side of a boundary.
* Develops understanding of why pressure in a fluid increases with depth.
* Uses understanding of pressure at different depths of a fluid to explain how pressure pushes on an object submerged in a fluid.

**What does the research say?**

**Common misunderstandings of pressure.**

Students very commonly think of pressure as a weight or a force, which has a preferred downwards direction in fluids (Psillos, 1999; Kariotoglou and Psillos, 2019).

**Textbooks often introduce pressure in a way that can consolidate misunderstanding.**

Psillos (1999) examined how textbooks develop an understanding of pressure and found that they nearly always introduce pressure as a measure of how concentrated a force is and use the equation ‘P=F/A’ to define it. Usually, examples of solids pushing down onto a surface are used to consolidate understanding and in these examples surface pressure is a vector quantity acting in one direction. From such an introduction, students can interpret pressure wrongly as a ‘pressing force’ and may (as some textbooks do) describe a fluid ‘exerting a pressure’. This misunderstanding is compounded by diagrams that usually indicate pressure with arrows that are visually indistinguishable from force arrows. It is instead, correct to say that ‘a fluid has pressure’ and a ‘force is exerted’ (Kariotoglou and Psillos, 1993).

In order to think about pressure in liquids and gases, students cannot simply extend ideas about surface pressure (Driver et al., 1994). In contrast to pressure between solid surfaces, pressure in a fluid is a scalar quantity, yet few students think of pressure acting in all directions in air or water and textbooks rarely make explicit the conditions in which each interpretation of pressure should be applied (Psillos, 1999).

**It is effective to develop a qualitative understanding of pressure and the causes of pressure before introducing calculations.**

The influence of the approach commonly used in text books perhaps partly explains the observations of Liang, Chou and Chiu (2011) and Sanger et al. (2013), that it is common for students to be able to solve pressure calculations, whilst not being able to explain the phenomena involved.

To help avoid common misunderstandings of pressure in a fluid, Kariotoglou and Psillos (2019) suggest introducing pressure as a primary concept that can be directly measured, rather than as a derived quantity. They recommend the relationship between force and pressure, F = P x A, is introduced near the end of a teaching sequence as the force exerted on a surface because of pressure that a fluid has (Kariotoglou and Psillos, 1993). The force of a fluid on a surface is always a vector and the equation can be extended to interactions between solid surfaces.

**Particle model of pressure in fluids.**

Following large scale studies of students’ conceptions about gases (n=600, age 11-13) and fluids (n=944, age 14-20) by Séré (1986) and Besson (2004) respectively, both researchers conclude that there is a need for students to systematically reason how the motion of particles cause pressure effects, as a preliminary step in the study of pressure. Ideas about the movement of particles in a fluid can then be used to explain why the force on a surface, F = P x A.

Before using a particle model to explain pressure, it may be necessary to resolve students’ misunderstandings about the motion and distribution of particles in gas. In their study of US college students on a general chemistry course (n=378, age 17-18) Sanger et al. (2013) found that although 85% understood how particle speeds increased or decreased with temperature, only 51% predicted the correct distribution of particles in a gas after its temperature had been reduced. Rather than thinking of particles evenly distributed throughout a container, and moving at a slower average speed; nearly half thought that the slowing down of particles in a gas meant that they moved more closely together and clustered in one region of a container.

**A description of pressure without an equation.**

The concept of pressure was formulated to interpret macroscopic observations of fluids at rest, in terms of force and related concepts (Psillos, 1999). Pressure of a fluid can be thought of as a measure of how hard its particles are, on average, pushing each other apart. Pressure of a fluid increases if its particles collide with more speed (momentum) and/or if they bump into each other more frequently. The random motion of an unimaginably large number of unconnected particles in a fluid results in pressure being equal in all directions.

It is because particles in a fluid effectively push apart equally in all directions that the pressure a fluid has is a scalar quantity. When particles in a fluid collide with the walls of a container, or an object in the fluid, they do so from just one side of a surface and so push on it with a force in one particular direction.

**Guidance notes**

The force that a particle exerts on a surface is equal to the rate of change of momentum of the particle hitting the surface. The total force on a surface is the sum of forces exerted by all the particles hitting the surface, and pressure is measured as the force exerted on one square metre (or one square centimetre) of the surface. These are ideas that some students may use in their later studies to derive the ideal gas equation.

Some courses for 14- to 16-year-olds combine the equations for pressure (P=F/A), weight (w=mg) and density (ρ=m/V) in order to calculate pressure at a depth under the surface of a fluid using p=ρgh.

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