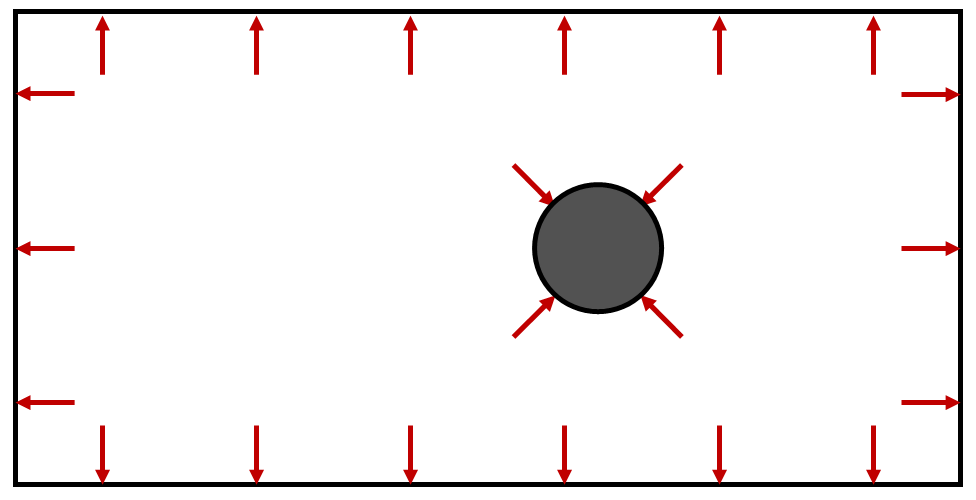
**Force and pressure**

A gas can exert force on an object because it has pressure.

A gas can exert force on the walls of its container because it has pressure.

Like gases, liquids have pressure and exert force on a surface.



**A gas** (or liquid)

**has pressure everywhere**

**in the container.**

**Force is exerted by the gas** (or liquid) **on every surface.**

**a.** Which changes would make the force on the object the biggest?

*Put a tick (✓) in the box next to the best answer.*

|  |  |  |
| --- | --- | --- |
| **A** | Triple the pressure – nothing else. |  |
|  |  |  |
| **B** | Double the pressure and double the size of the object. |  |
|  |  |  |
| **C** | Double the pressure and halve the size of the object. |  |
|  |  |  |
| **D** | Triple the size of the object – nothing else. |  |

**b.** Which equation best explains your answer to the last question?

|  |  |  |
| --- | --- | --- |
| A | B | C |
|  |  |  |
| Force is equal to the pressure times by the area of the surface. | Force is equal to the pressure divided by the area of the surface. | Force is equal to the area of the surface added to the pressure. |

*Physics > Big idea PMA: Matter > Topic PMA4: Particle explanations > Key concept PMA4.2: Pressure*

|  |
| --- |
| **Diagnostic question** |
| **Force and pressure** |

**Overview**

|  |  |
| --- | --- |
| 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. |
| Observable learning outcome: | Interpret the equation F = P x A. |
| Question type: | Two-tier multiple choice |
| Key words: | Pressure, force, area of a surface |

**What does the research say?**

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 physics each symbol in an equation is connected to a physical variable. Students are required to perform mathematical operations with the equation and then connect the mathematical operations and the results of calculations to their implications in the physical world (Redish and Kuo, 2015). To show mastery in physics students should be able to explain their equations in words, however at age 14-16 students often hide an incomplete understanding as they can calculate correct answers by treating equations just as mathematical operations without a good understanding of the physics that may be necessary for their future studies.

Redish and Kuo (2015) suggest for many students, the first step in physics calculations needs to be highlighting the physical meaning, which can later be tied to the formal mathematical laws. This can help students by giving meaning to equations, so analysis of problems is no longer a ‘brittle rote procedure’. It can also lead to conceptual short cuts that enable students to access more challenging problems. For many experienced physicists, physical meaning is gained by beginning with the mathematical relations that come easily to them, but their strategy is less effective for many learners.

These questions explore students’ understanding of the relationship between pressure, force and surface area.

**Ways to use this question**

Students should complete the questions individually. This could be a pencil and paper exercise, or you could use an electronic ‘voting system’ or mini white boards and the PowerPoint presentation. The follow on question will give you insights into how they are thinking and highlight specific misconceptions that some may hold.

If there is a range of answers, you may choose to respond through structured class discussion. Ask one student to explain why they gave the answer they did; ask another student to explain why they agree with them; ask another to explain why they disagree, and so on. This sort of discussion gives students the opportunity to explore their thinking and for you to really understand their learning needs.

*Differentiation*

You may choose to read the questions to the class, so that everyone can focus on the science. In some situations it may be more appropriate for a teaching assistant to read for one or two students.

**Expected answers**

1. B

2. A

**How to respond - what next?**

a. Doubling the pressure of a fluid doubles both how hard its particles push away from each other, and the force they exert on a surface. If the surface area is also doubled, twice as many particles will be able to collide with it and the force on the surface will double again. Doubling both the pressure and the surface area of the object makes the force on it four times bigger.

Option A is the one with the largest pressure and students choosing it are likely to hold the misunderstanding that pressure is a pressing force: the bigger the pressure, the bigger the force.

Option C is suggestive of a more concentrated force and may make sense to students who do not have a clear understanding of the distinction between force and pressure. Starting from the wrong premises it can be misinterpreted as: twice the ‘force’ concentrated onto half the surface area gives four times the ‘pressure’.

A few students may choose option D if they misunderstand that the size of the force is represented by the number of force arrows. Instead, the total force is represented by both the number of force arrows and their size. Some students may guess between options A and D.

b. This question allows students to fit their understanding of the relationship between pressure, force and surface area into a mathematical formula. Option A is the only one for which force doubles if either pressure or surface area is doubled.

Option C addresses the understanding that units of added quantities must be consistent.

If students have misunderstandings about interpreting the relationship F = P x A, it can help to guide students through an understanding of what the particles in the fluid are doing for each change that is described. Careful questioning can elicit the understanding that:

* increasing pressure increases the frequency and/or the speed at which particles collide with a certain sized area on the surface of the object
* doubling the pressure doubles the force against a fixed area of the surface
* doubling or tripling the area gives room for two or three times as many particles to collide with it
* total force increases in proportion to the area of the object.

If students understand the relationship but not why F = P x A represents the relationship, it can help to ask student to reason what will happen when pressure and area are doubled or halved, and so on, and to put simple numbers into the equation to show how it gives the right answers.

Once students can explain the equation F = P x A, they could then practise using the equation to calculate answers to problems.

**Acknowledgments**

Developed by Peter Fairhurst (UYSEG).

Images: Peter Fairhurst (UYSEG).

**References**

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