# Oxford Sparks

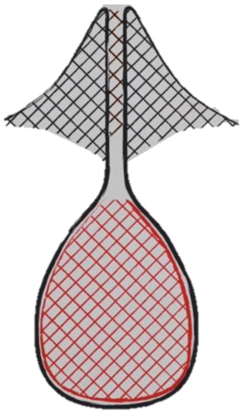
# Pressure in Liquids

Suitable for UK KS4 or ages 14-16

## Notes for teachers

### At a glance

The following resource uses the context of volcanoes to explore the concept of pressure at KS4 level. Students will use equations and make calculations related to pressure & depth, pressure, force & area, and Boyle's Law.



### Learning Outcomes

- Students practice using equations for calculations and to explain phenomenon

### Each student will need

- A copy of the student worksheet

### Possible Lesson Activities

1. **Starter activity**
    - Show the School Science Out There video outlining a PhD student's research into volcanoes.
    - Highlight the equations used.
2. **Main activity: Calculations worksheet**
    - Hand out student calculations worksheet.
    - Circulate to help and engage students with task.

**3. Main activity: Calculation worksheet answers**

- Hand out worksheet and circulate. For weaker ability sets it may be helpful to provide access to resources where students look up relevant equations (e.g. textbooks).

- *Q1 - What is the equation that links pressure with depth within a body of liquid?*
  - *A – $P = \rho gh$ $\rho$ = density =kg/$m^3$ g = gravitational field strength = N/kg h = depth = m*
- *Q2 - Use your equation to explain why the greatest pressures are within a magma chamber are found at the bottom.*
  - *A – Depth is a factor in the pressure equation. With increased depth, there is a greater weight due to the column of fluid above.*
- *Q3 - Calculate the pressure in a magma chamber at a depth of 2km. Assume the density of magma is 2650kg/$m^3$ and gravitational field strength is 9.8N/kg.*
  - *A – Pressure = 2650 x 9.8 x 2000 = 51,940,000Pa*
- *Q4 - Calculate the difference in pressure between magma at a depth of 6km and at a depth of 10km. Again, assume the density of magma is 2650kg/$m^3$ and gravitational field strength is 9.8N/kg.*
  - *A – Pressure = 2650 x 9.8 x 3000 = 77,910,000Pa*
- *Q5 - The density of magma can have an effect on the pressures that develop within the magma chamber. Explain why.*
  - *A – Density a factor in the pressure equation. With increased density (e.g., a magma with fewer trapped gas bubbles), there is a greater weight above due to the column of fluid above at a given depth and conversely with decreased density (e.g., a magma with more trapped gas bubbles in it) there is less weight above due to the column of fluid above at a given depth.*
- *Q6 - What would the pressure at a depth of 2km be if the magma chamber contained a more dense magma with a density of 2.81g/$cm^3$ (note the different units – the students might need reminding about how to convert).*
  - *A – Pressure = 2000 x 2810 x 9.8 = 55,076,000Pa*
- *Q7 - State the equation that links pressure with force and area.*
  - *A – P = F/A F = force = N A = area = $m^2$ P = pressure = Pa*
- *Q8 - State the direction of the force exerted by the liquid magma on the walls of the magma chamber.*
  - *A – Perpendicular to the wall of the container*
- *Q9 - Use your answers from the previous section to explain whether the magma chamber walls at the top or bottom of the chamber experience a greater pressure.*
  - *A – The bottom due to greater depth.*
- *Q10 - At the bottom of a magma chamber (10km down) the pressure can be in excess of 250,000kPa. Calculate the force applied by the magma on an area of the magma chamber wall 10$m^2$.*
  - *A – Force = PxA = 250,000,000 x 10 = 2,500,000,000N*
- *Q11 - At less depth within the magma chamber, pressures are lower. At a dept of 2.1km the pressure is 52.5MPa. Calculate the area of magma chamber wall that would experience the same force as that exerted on 10$m^2$ of chamber wall at a depth of 10km.*
  - *A = F/P = 2,500,000,000 / 52,500,000 = 47.62$m^2$*

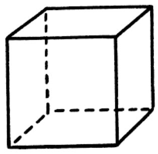
- *Q12 - When a volcano is active but not exploding or extruding magma onto the surface, pressure within the magma storage area can still result in a force being applied to the 'lid' of the magma vent. If the 'lid' of the vent remains stationary, what can we assume about the size and direction of the force exerted by the 'lid'?*
  - *A – Equal and opposite to the force applied by the magma. If there was a resultant force, the lid of the magma chamber would move.*
- *Q13- Using both the pressure equations you have practised above, explain whether an object would experience more upthrust if (theoretically!) submerged in a more or less dense magma.*
  - *A – An object would experience more upthrust in a more dense medium. For each change in depth, there is a greater change in pressure for a given change in depth. Therefore, there would be a greater difference in the force exerted on the bottom of the object (which is at greater depth) then the top and so it would experience greater upthrust.*
  - *Note to teachers – in fact lavas/magmas are not simple liquids like water as the silicon and oxygen within them can form chains and networks (polymerisation) and they contain phenocrysts and gas bubbles. Consequently, they often do not behave as Newtonian fluids. They have a threshold yield strength that must be overcome before the flow will move. This type of fluid is a Bingham Fluid.*
- *Q14 - State Boyle's law and given equations that represent it.*
  - *A - The pressure of a given mass of an ideal gas is inversely proportional to its volume at a constant temperature.*
  - $P_1V_1 = P_2V_2$
- *Q15 - For example, a sample of gas at standard temperature and pressure (STP: 1atm or 100,000Pa & 0˚C) has a volume of 350cm$^3$. Calculate the volume of the gas sample if pressure was increased to 182,000Pa.*
  - *A -* $P_1V_1 = P_2V_2$
  - $100,000 \times 350 = 182,000 \times V_2$
  - $V_2 = 35,000,000 / 182,000$
  - $V_2 = 192.3cm^3$
- *Q16 - For example, a sample of gas at standard temperature and pressure (STP: 1atm or 100,000Pa & 0˚C) has a volume of 802cm3. Calculate the pressure the gas sample is under when its volume is exactly 1dm$^3$.*
  - *A -* $P_1V_1 = P_2V_2$
  - $100,000 \times 802 = P_2 \times 1000$
  - $P_2 = 80,200,000 / 1000$
  - $P_2 = 80,200Pa$
- *Q17 - Suggest why Boyle's law cannot be used to predict the volume of a gas bubble within a magma chamber, even if the pressure and volume of an equal mass of gas are known at STP.*
  - *A – There is a significant temperature change between a lab and a magma chamber. Boyle's Law is only true for gases at a constant temperature.*

**4. Plenary**

- Show video about Mont St. Helens https://www.youtube.com/watch?v=Ec30uU0G56U
- Ask students to explain how expansion of the magma chamber helped regulate pressure in the build-up to the eruption. If short on time, this is shown in the 1st half of the video although the rest provides further interesting context for the calculations completed.

**5. Homework**

- Using the concept of a closed system box filled with a gas, ask students to use kinetic theory and the idea of collisions to write a short paragraph explaining why pressure increases with increasing temperature but decreases with increasing volume.



**Web links**

Oxford Sparks video 'Using your science to understand volcanic eruptions':

https://www.oxfordsparks.ox.ac.uk/content/using-your-science-understand-volcanic-eruptions

Mount St. Helens Video https://www.youtube.com/watch?v=Ec30uU0G56U

**Further Information**

Video Shows What Really Happens When You Step on Molten Lava (obvious safety warning!): https://www.techeblog.com/video-shows-what-really-happens-when-you-step-on-molten-lava/