

Gas pressure and volume

AQA GCSE Separate Physics 8463 | Paper 1 | Foundation and Higher pathways

Worked answers | 29 parts and 52 marks per pathway | 34 printed parts

Specification points covered

8463 4.3.3.1: particle motion, temperature and gas pressure

8463 4.3.3.2: pressure forces and $pV = \text{constant}$ for a fixed mass at constant temperature

8463 4.3.3.3: work done on a gas, internal energy and temperature — Higher section 7 only

A rescue-equipment team tests the sealed air chamber used to model a portable lifting cushion. They compare controlled slow changes with a rapid compression. Each test starts with the stated conditions.

Original PhysicsUK practice, not an official AQA resource. Common sections 1–5 plus ONE final pathway per pupil. Section 7 replaces section 6; it is not extra work. Credit equivalent methods and consistent error carried forward. Do not extend Boyle's law to a stage with a changed temperature or gas mass.

1 Choosing the correct model

In the initial test the chamber is sealed. Its piston can be locked so the gas volume is fixed. The team can also move the piston slowly while keeping the air at the room temperature.

1(a) State the two conditions needed for Boyle's law to apply. **[2 marks]**

Answer / mark points: A fixed mass of gas. [1] Constant temperature. [1] Constant volume is not a condition for a pressure–volume comparison.

1(b) State the SI unit of pressure. **[1 mark]**

Answer / mark points: Pascal (Pa). [1] Not newton; pressure is force per unit area.

1(c) The piston is locked and the sealed gas warms from 20 °C to 35 °C. Explain, using particles, why the pressure increases. **[3 marks]**

Answer / mark points: The molecules have greater mean kinetic energy/move faster on average. [1]

They collide with the walls more frequently and/or exert a greater force in collisions. [1]

The average force per unit wall area increases, so the pressure increases. [1] Do not say the particles themselves expand.

1(d) Why can $p_1V_1 = p_2V_2$ not be used to predict the pressure change in 1(c)? **[1 mark]**

Answer / mark points: The gas temperature changes, so the constant-temperature condition is not met. [1] A fixed mass alone is insufficient.



1 Choosing the correct model continued

1(e) In another test, more air is pumped in while volume and temperature stay the same. Explain why pressure increases, and identify which Boyle-law condition is no longer met. **[2 marks]**

Answer / mark points: More molecules give more wall collisions per second and hence a greater pressure at this fixed volume/temperature. [1]
The mass of gas is no longer fixed. [1] Do not attribute this rise to faster molecules when temperature is unchanged.

2 Forces in the sealed chamber

Figure 1 shows the test rig, not the full lifting cushion. Volumes in this worksheet include all trapped gas in the chamber and sensor connection. Only the force exerted by the trapped air on the piston is requested; do not include forces from the operator or air outside it.

2(a) On Figure 1, draw one arrow labelled F to show the force exerted by the trapped air on the piston. **[1 mark]**

Answer / mark points: A horizontal arrow on the piston pointing to the right, away from the trapped gas. [1] The teacher figure shows F ; this is not a resultant-force diagram.

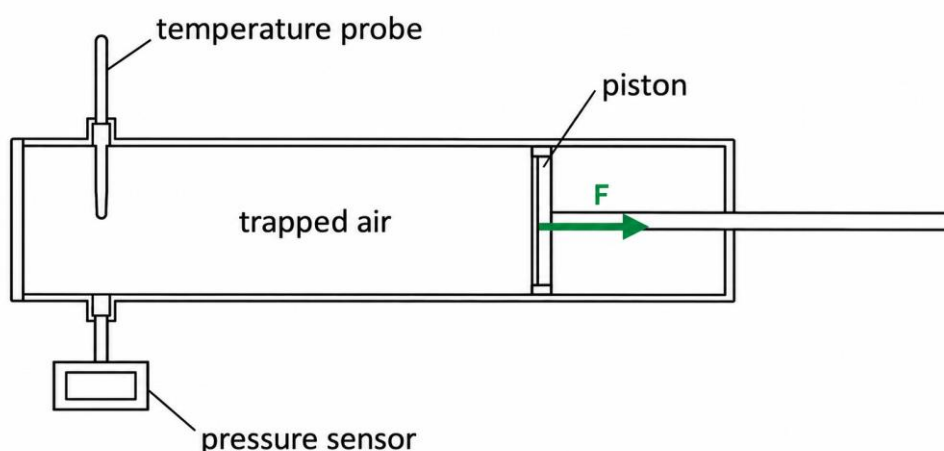


Figure 1

2(b) State the angle between this force and the flat piston face. **[1 mark]**

Answer / mark points: 90° ; it acts at right angles to the face. [1] The angle is to the surface, not to the horizontal.

2(c) The piston is moved inwards slowly. The mass and temperature stay constant. Explain why the pressure of the trapped air increases. **[3 marks]**

Answer / mark points: The same molecules occupy a smaller volume/return to the walls over shorter distances. [1]
Wall collisions occur more frequently, giving a greater average force on a given wall area. [1]
Greater average force per unit area means greater pressure. [1] Mean kinetic energy and mean speed remain unchanged at constant temperature.

2(d) A trainee says, "The air can be compressed because the molecules get smaller." Correct this statement in terms of molecular size and separation. **[2 marks]**

Answer / mark points: The molecules do not become smaller. [1]
The large spaces between molecules are reduced; their average separation decreases. [1] The number of molecules is unchanged in this sealed test.



3 Predicting pressure and volume

Each part is a separate slow test with a fixed mass of air at constant temperature. Use $p_1V_1 = p_2V_2$. Check that corresponding units match before substituting. State units in every answer.

3(a) Air at 100 kPa occupies 600 cm³. It is compressed to 300 cm³. Calculate the final pressure. **[2 marks]**

Answer / mark points: $p_2 = p_1V_1 / V_2 = 100 \times 600 / 300$. [1]
 $p_2 = 200$ kPa. [1] Halving volume doubles pressure.

3(b) Air at 120 kPa occupies 900 cm³. Its pressure becomes 180 kPa. Calculate the final volume. **[2 marks]**

Answer / mark points: $V_2 = p_1V_1 / p_2 = 120 \times 900 / 180$. [1]
 $V_2 = 600$ cm³. [1] Pressure increases, so the volume must decrease.

3(c) Air at 150 kPa occupies 0.80 L. It is compressed to 200 cm³. Calculate the final pressure. **[2 marks]**

Answer / mark points: 0.80 L = 800 cm³ (or 200 cm³ = 0.200 L). [1]
 $p_2 = 150 \times 800 / 200 = 600$ kPa. [1] Both volume units must match.

3(d) Air at 320 kPa occupies 250 cm³. It expands until its pressure is 200 kPa. Calculate its new volume. **[2 marks]**

Answer / mark points: $V_2 = 320 \times 250 / 200$. [1]
 $V_2 = 400$ cm³. [1] Expansion is consistent with a pressure decrease.

3(e) For a different chamber, $p = 100\,000$ Pa and $V = 0.000600$ m³. Calculate the value of pV , giving its units as Pa m³. **[1 mark]**

Answer / mark points: $pV = 100\,000 \times 0.000600 = 60$ Pa m³. [1] Keeping consistent Pa and m³ units gives this value; it is not numerically 60 000 as in kPa cm³.

3(f) A test chamber starts at 100 kPa and 900 cm³. Its permitted pressure is at most 450 kPa. Calculate the pressure at 180 cm³ and decide whether this meets the stated limit. Show your working. **[2 marks]**

Answer / mark points: $p_2 = 100 \times 900 / 180 = 500$ kPa. [1]
 It does not meet the limit: 500 kPa is above 450 kPa. [1] For this explicit Show your working task, a bare answer with no working earns at most 1 mark. Do not infer complete operational safety from a pressure check.



4 Reading the pressure volume evidence

Figure 2 shows the same fixed mass at 20 °C. Read the graph where requested.

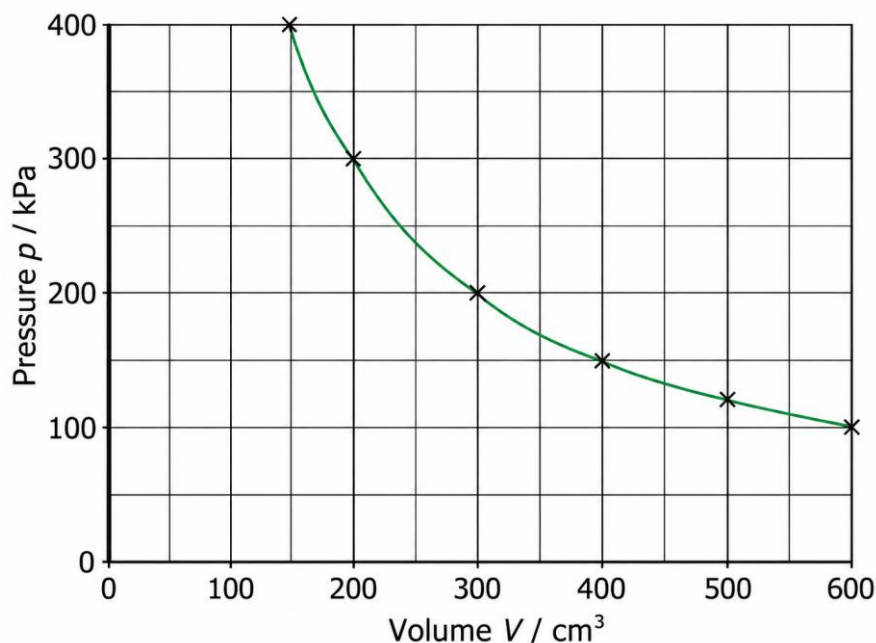


Figure 2

4(a) Read the pressure when the volume is 400 cm³. **[1 mark]**

Answer / mark points: 150 kPa. [1] Allow 145–155 kPa for graph reading; this lies halfway between 100 and 200 kPa.

4(b) Read the volume when the pressure is 200 kPa. **[1 mark]**

Answer / mark points: 300 cm³. [1] Allow 290–310 cm³ for reading from the graph.

4(c) Use the plotted values at 200 cm³ and 400 cm³ to show that the graph is consistent with inverse proportionality. **[2 marks]**

Answer / mark points: Pressure changes from 300 kPa to 150 kPa as volume changes from 200 cm³ to 400 cm³. [1]

Doubling the volume halves the pressure, so these points support inverse proportionality (both products are 60 000 kPa cm³). [1] “One increases as the other decreases” alone is insufficient.

4(d) A trainee reads 80 kPa at 500 cm³. Correct this reading, then check the corrected point by calculating pV . **[2 marks]**

Answer / mark points: Correct reading: 120 kPa (allow 115–125 kPa). [1]

$pV = 120 \times 500 = 60\,000 \text{ kPa cm}^3$, consistent with the other points. [1] A reading of 80 kPa gives 40 000 kPa cm³.

4(e) Use Boyle’s law to predict the pressure at 100 cm³. Explain why this value cannot be read from Figure 2. **[2 marks]**

Answer / mark points: $p = 60\,000 / 100 = 600 \text{ kPa}$. [1]

This is above the vertical scale maximum of 400 kPa, so the plotted curve does not show that point. [1] This prediction assumes the same fixed mass and temperature.

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5 Checking the investigation

Table 1 gives separate slow-compression trials. Before EACH trial, the chamber is refilled and reset to 600 cm³, 100 kPa and 20 °C. The table gives the final readings. The temperature readings agree within the display resolution of 0.1 °C.

Table 1

Final volume / cm ³	Final pressure / kPa	Final temperature / °C
600	100	20.0
400	150	20.1
300	180	20.0
200	300	20.0

5(a) Calculate pV for each row. Identify the reading that is inconsistent with the other three and use your products as evidence. **[2 marks]**

Answer / mark points: Products in row order: 60 000, 60 000, 54 000, 60 000 kPa cm³. [1 for all]
The 180 kPa reading at 300 cm³ is inconsistent: its product is 54 000, rather than 60 000 kPa cm³. [1] The data identify a mismatch, not its cause on their own.

5(b) A check finds that a valve was accidentally opened during the 300 cm³ trial. Use the particle model to explain why losing air can give a lower pressure at the same volume and temperature. **[2 marks]**

Answer / mark points: There are fewer molecules in the chamber. [1]
There are fewer wall collisions per second/lower average force per unit area, so pressure is lower. [1] The molecules do not need to become slower at the same temperature.

5(c) State how the team should check the two Boyle-law conditions before recording a valid pressure–volume pair. **[2 marks]**

Answer / mark points: Check that the valve/seals are airtight and no gas enters or leaves. [1]
Wait after each piston movement and use the temperature probe to check that the gas has returned to the same stable temperature before reading p and V . [1] Moving slowly alone does not prove a constant temperature.

5(d) A trainee proposes repeating the test many times with the same leaking valve and taking a mean. Explain why this does not correct the problem. **[2 marks]**

Answer / mark points: A mean does not restore the fixed mass/remove the loss of gas caused by the leaking valve. [1]
The leak must be repaired/prevented and the chamber reset before valid comparisons are made. [1]
Repeats may reduce random variation, not cure this change in the system.

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6 Foundation replacement section

Foundation: complete this section after sections 1–5, then stop. Higher pupils skip this page. The team uses a second sealed chamber. In 6(a), 6(c) and 6(d), it starts at 1.20 L and 100 kPa. All changes are slow at 20 °C with no leak. The allowed pressure is at most 400 kPa; this is a stated test limit, not a safety approval.

6(a) The second chamber is compressed from 1.20 L to 0.40 L. Calculate its new pressure. **[2 marks]**

Answer / mark points: $p_2 = 100 \times 1.20 / 0.40$. [1]

$p_2 = 300$ kPa. [1] Both volumes may remain in litres because their units match.

6(b) A separate test starts at 120 kPa and 750 cm³. Calculate the volume when pressure reaches 250 kPa. **[2 marks]**

Answer / mark points: $V_2 = 120 \times 750 / 250$. [1]

$V_2 = 360$ cm³. [1]

6(c) Return to the 1.20 L, 100 kPa starting state. Calculate the minimum volume allowed by the 400 kPa limit. Give your answer in cm³. Show your working. **[2 marks]**

Answer / mark points: Minimum $V = 100 \times 1.20 / 400 = 0.300$ L. [1]

Minimum volume = 300 cm³. [1] Any smaller volume would exceed 400 kPa at the same temperature. For this explicit Show your working task, a bare answer with no working earns at most 1 mark.

6(d) A trainee says that compressing this sealed chamber to half its volume removes half its molecules. Explain why this is wrong. **[1 mark]**

Answer / mark points: No gas enters or leaves, so the number of molecules remains the same; only their average separation changes. [1 for the correction with reason]

6(e) Two chambers with identical piston faces are each held at 20 °C. A has an internal pressure of 200 kPa and B has 300 kPa. Which trapped gas exerts the larger force on its piston? Explain using pressure and area. **[2 marks]**

Answer / mark points: B exerts the larger force. [1]

Its pressure is higher on the same piston area, and pressure is force per unit area. [1] Compare only the trapped-gas forces, not the resultants including outside air or supports.



7 Higher replacement section

Higher only: complete this section INSTEAD of section 6. Foundation pupils do not attempt it. A fresh sealed chamber starts at 500 cm^3 , 120 kPa and 20°C . A ram rapidly pushes the piston to 250 cm^3 . Little energy is transferred to the surroundings during this short compression. The measured pressure immediately afterwards is 300 kPa and the gas is warmer. The piston is then locked at 250 cm^3 while the gas cools back to 20°C . No gas enters or leaves.

7(a) Explain how the ram transfers energy to the gas during the rapid compression. State what happens to the gas's internal energy. **[2 marks]**

Answer / mark points: The ram does work on the gas: a force moves the piston and transfers energy to the gas. [1]

The gas's internal energy increases, since little energy leaves during this short compression. [1]
"Energy is created" is incorrect; this need not be energy transferred by heating.

7(b) Explain the observed temperature rise in terms of the molecules. **[1 mark]**

Answer / mark points: The mean kinetic energy of the gas molecules increases. [1] Temperature is related to mean molecular kinetic energy; do not say each molecule has the same speed or that temperature itself is energy.

7(c) Calculate the pressure Boyle's law would predict at 250 cm^3 if the gas stayed at 20°C . Explain why that result need not match the observed 300 kPa immediately after rapid compression. **[2 marks]**

Answer / mark points: Constant-temperature prediction: $p_2 = 120 \times 500 / 250 = 240 \text{ kPa}$. [1]

The observed gas is warmer, so the constant-temperature condition is not met during rapid compression; that Boyle-law comparison is invalid. [1] Do not apply $pV=\text{constant}$ across this changed-temperature stage.

7(d) The piston stays locked at 250 cm^3 while the sealed gas cools. Explain, using particles, why its pressure falls. **[3 marks]**

Answer / mark points: Mean molecular kinetic energy/speed decreases as the gas cools. [1]

Molecules collide with the walls less frequently. [1]

The average force per unit wall area decreases, so pressure decreases. [1] Weaker individual collisions also contribute. The gas does not expand: volume is locked.

7(e) Once the gas is back at 20°C , may its state be compared with the original 500 cm^3 state using Boyle's law? Explain. **[1 mark]**

Answer / mark points: Yes: it is the same fixed mass and both compared states are at 20°C . [1 for decision with both conditions] It should then be 240 kPa at 250 cm^3 ; the intervening hot stage does not prevent comparing the two equal-temperature endpoints.

Review and improve

Use the full chain: wall collisions $\rightarrow$ average force per unit area $\rightarrow$ pressure. At constant temperature, compression does not increase mean molecular speed. Higher rapid compression transfers energy by work, not necessarily by heating. Timing is estimated and untried; no required-practical completion claim.

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