

Pressure in Gases

Mark Scheme



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1. Whether inflating a balloon or a bicycle tyre, gas pressure is caused by the combined force of billions of microscopic particles constantly colliding with the inside walls of their container.
- a) A gas is trapped inside a syringe at a constant room temperature. If the plunger is pushed in, halving the volume of the gas, what happens to the pressure?

C – is the only correct answer.	1 mark
	Total: 1 mark

- b) The figure below shows some air inside a movable piston in the shape of a cylinder.

The piston is pulled 2 cm in the direction of the arrow, but stays in the cylinder.

One of the following increases. Which one of the following increases?

C – is the only correct answer.	1 mark
	Total: 1 mark

- c) Why does atmospheric pressure decrease as you climb higher up a mountain?

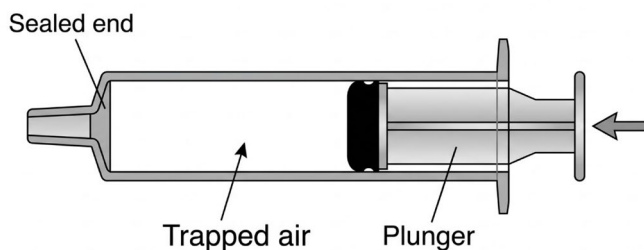
D – is the only correct answer.	1 mark
	Total: 1 mark

- d) A gas has a volume of 2.0 m^3 at a pressure of $100\,000 \text{ Pa}$.
If the gas is allowed to expand to a volume of 4.0 m^3 at a constant temperature, what will the new pressure be?

B – is the only correct answer.	1 mark
	Total: 1 mark

(Total for Question 1 is 4 marks)

2. A student is investigating how the volume of a trapped gas affects its pressure.
The figure below shows the equipment used in the investigation



- a) Describe, in terms of particles, how the trapped air exerts a pressure on the inside walls of the syringe.

A description to include any two of the following:	
• Air particles collide with the walls (of the syringe). • These collisions exert a force on the walls. • Pressure is the total force exerted over a given area.	
	Total: 2 marks

- b) A student slowly pushes the plunger inward, decreasing the volume of the trapped air.
The temperature of the air remains constant.

Explain, using the particle model, why the pressure of the trapped air increases.

An explanation to include the following:	
Space: The particles are closer together / same number of particles in a smaller volume.	1 mark
Collisions: So the particles collide with the walls more frequently / there is a higher rate of collisions.	1 mark
Force: Causing a greater (total) force to be exerted on the walls.	1 mark
	Total: 3 marks

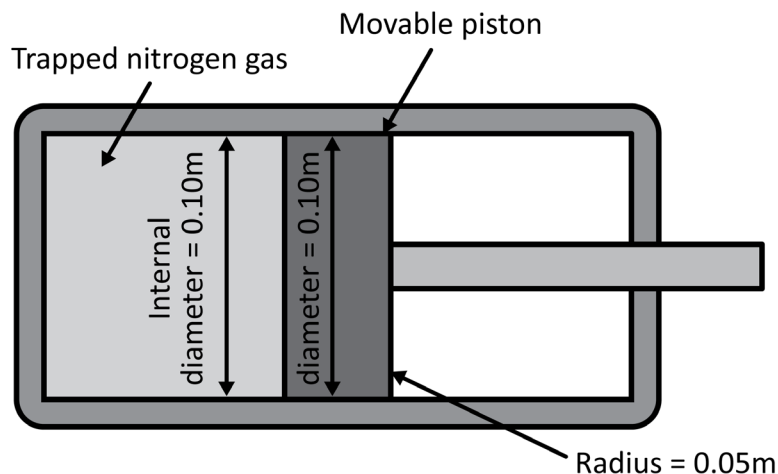
- c) Before the plunger is pushed in, the trapped air has a volume of 24 cm^3 and a pressure of $100\,000 \text{ Pa}$.
The student pushes the plunger in until the volume of the air is 15 cm^3 .

Assuming the temperature remains constant, calculate the new pressure of the gas.

Equation and substitution: $p_1 \times V_1 = p_2 \times V_2$	1 mark
$100000 \times 24 = p_2 \times 15$	
$p_2 = 2400000 \div 15$	1 mark
Final value: 160 000	1 mark
	Total: 3 marks

(Total for Question 2 is 8 marks)

3. An engineer is testing a sealed cylinder containing a fixed mass of nitrogen gas at a constant room temperature. The figure below shows the cylinder the engineer used.



- a) The trapped nitrogen gas has an initial volume of 0.060 m^3 and an initial pressure of $150\,000 \text{ Pa}$. Calculate the total outward force exerted by the initial gas pressure on the circular piston.

Area = $\pi \times 0.05^2$	
Area = $0.00785 \text{ (m}^2\text{)}$	1 mark
Force = 150000×0.00785	1 mark
Force = 1178 (N)	
	Total: 2 marks

- b) A machine pushes the piston inwards, compressing the gas to a new volume of 0.025 m^3 . The temperature of the gas remains constant. Calculate the new pressure of the trapped gas. Give your answer in standard form.

Equation and substitution: $150000 \times 0.060 = p_2 \times 0.025$	
Rearrangement and value: $p_2 = 9000 \div 0.025$	1 mark
$p_2 = 360000 \text{ (Pa)}$	1 mark
Standard form: 3.6×10^5	1 mark
	Total: 3 marks

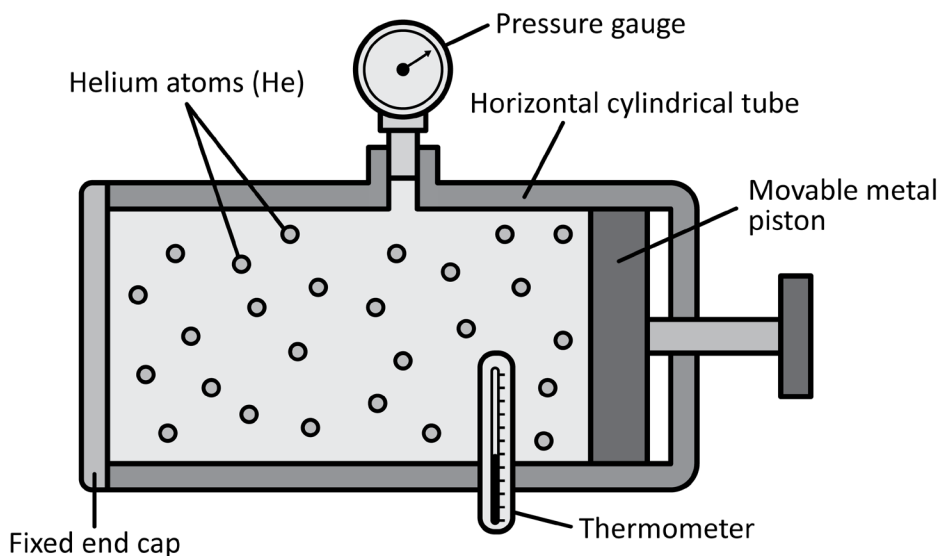
- c) Using your answers from previous parts, calculate the new outward force exerted by the gas on the piston after it has been compressed.

Give your answer to **3 significant figures**.

Substitution: force = 360000×0.00785	1 mark
Force = $2827(.4)$	1 mark
Significant figures: 2830	1 mark
Accept an alternative method that gets the same answer.	
	Total: 3 marks

(Total for Question 3 is 8 marks)

4. A scientist is investigating the properties of a gas. The figure shows a sealed metal cylinder containing helium gas. The cylinder has a tightly fitting, movable piston.



- a) Explain, in terms of the motion of helium atoms, how the gas exerts a pressure on the inside of the cylinder.

Any three from:	
- Helium atoms/particles are in continuous / random motion. - Atoms/particles collide with the inside walls of the cylinder. - Each collision exerts a force on the wall. - Pressure is the (total) force exerted per unit area.	
	Total: 3 marks

- b) The scientist slowly pushes the piston inwards. The temperature of the helium gas remains constant.

Calculate the final pressure of the gas in kPa.

Equation / substitution: $120 \times 0.050 = p_2$	1 mark
Rearrangement: $p_2 = 6 \div 0.020$	1 mark
Final value: 300	1 mark
	Total: 3 marks

- c) The cross-sectional area of the movable piston is 0.0040 m^2 .

Using your answer from Part (b), calculate the outward force exerted by the helium gas on the piston after it has been compressed.

Converts pressure to Pa: 300,000	1 mark
Force = $300,000 \times 0.0040$	1 mark
Final value: 1200	1 mark
	Total: 3 marks

- d) The scientist locks the piston in place so the volume of the gas cannot change.
She then heats the cylinder.

Explain, in terms of particles, why the pressure reading on the gauge increases.

Speed/energy: The particles gain kinetic energy / move faster.	1 mark
Allow: internal energy increases.	
Collision frequency: So they collide with the walls more frequently / at a higher rate.	1 mark
Reject: <u>collide more</u> without reference to time (must be more frequent or more often).	
Force: And they collide with the walls with a greater force / hit the walls harder.	1 mark
	Total: 3 marks

- e) Later, the scientist unlocks the piston and pushes it inwards very rapidly.
She notices that the reading on the thermometer goes up.

Explain why the temperature of the helium gas increases when it is compressed very quickly.

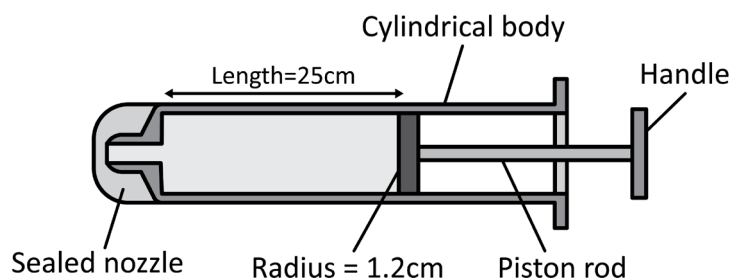
An explanation to include the following:	
Statement 1: Work is done on the gas (by the piston).	1 mark
Allow: energy is transferred to the gas mechanically.	
Statement 2: Which increases the internal energy / kinetic energy of the gas (particles).	1 mark
Allow: the piston transfers kinetic energy to the particles as it hits them.	
	Total: 2 marks

(Total for Question 4 is 14 marks)

5. A sealed cylindrical pump contains a fixed mass of air.
Initially, the length of the trapped air column is 25 cm and the pressure of the air is 101 000 Pa.

A student pushes the plunger inwards at a constant temperature until the length of the trapped air column is reduced to 10 cm.

The figure below shows the pump that the student uses.



Calculate the outward force exerted by the gas on the plunger in this new position.
Give your answer to 3 significant figures.

Area: converts radius to 0.012 m AND calculates $\text{Area} = \pi \times 0.012^2$ $\text{Area} = 4.52 \times 10^{-4} \text{ (m}^2\text{)}$	1 mark
Boyle's law substitution: $101000 \times 25 = p_2 \times 10$ New pressure: $p_2 = 252500$	1 mark
Force substitution: $\text{Force} = 252500 \times (4.52 \times 10^{-4})$	1 mark
Calculation: $114.2(28\dots)$	1 mark
Significant figures: 114	1 mark
	Total: 6 marks

(Total for Question 5 is 6 marks)