

Gas pressure, volume and the kelvin scale

Physics grades 9-10 (GCSE · IGCSE · O Level · Class 9-10) · Worksheet answers

Every answer states the law used, the substitution and the final value with its unit. Check that your temperatures were in kelvin where needed, and that both pressures and both volumes were in matching units. Small rounding differences in the last figure are acceptable.

Level: Physics grades 9-10 (GCSE · IGCSE · O Level · Class 9-10) · **Curriculum:** IGCSE 2.1, HS-PS3-2

Problem 1 Ideas of kinetic theory

Any three: the particles are in constant random motion; they are very far apart compared with their size; they move in straight lines between collisions; there are almost no forces between them except at collisions; the average kinetic energy depends on the temperature.

Problem 2 Celsius to kelvin

1. $0 + 273 = 273 \text{ K}$
2. $25 + 273 = 298 \text{ K}$
3. $-196 + 273 = 77 \text{ K}$
4. $300 - 273 = 27 \text{ °C}$

Problem 3 What raises the pressure?

- (a) **Increases:** faster particles hit harder and more often.
- (b) **Increases:** more collisions per second per unit area.
- (c) **Increases:** more particles, so more collisions.

Problem 4 Halving the room

$$p_2 = 100 \times 4.0 / 2.0 = 200 \text{ kPa}$$

Problem 5 Two boxes

1. **Box B.**
2. B has twice as many particles, so about twice as many collisions with the walls each second, giving about twice the pressure.

Problem 6 Squeezing a syringe

$$p_2 = 100 \times 40 / 25 = 160 \text{ kPa}$$

Problem 7 Filling a tyre

$$V_2 = p_1 V_1 / p_2 = 100 \times 600 / 300 = \mathbf{200 \text{ cm}^3}$$

Problem 8 Heating a rigid cylinder

$$T_1 = 293 \text{ K}, T_2 = 373 \text{ K}$$

$$p_2 = 150 \times 373 / 293 = 190.96 = \mathbf{191 \text{ kPa}}$$

Problem 9 Warning on an aerosol can

Heating makes the gas particles faster. They hit the walls harder and more often. The volume of the can is fixed, so **the pressure rises** and the can might burst, with the risk of injury.

Problem 10 Reading a pressure-volume graph

1. **250 kPa**

2. $2 \times 500 = 1000$, $4 \times 250 = 1000$, $10 \times 100 = 1000 \text{ kPa L}$. The product is constant, so **pressure is inversely proportional to volume** (Boyle's law).

3. $p = 1000 / 8 = \mathbf{125 \text{ kPa}}$

Problem 11 Weather balloon

$$V_2 = 100 \times 2.0 / 25 = \mathbf{8.0 \text{ m}^3}$$

Problem 12 Crisp packet on a hill

The air outside is at lower pressure at altitude. The pressure of the gas trapped inside is greater than outside, so the bag expands until the pressures balance. The mass of gas is the same, so **the volume rises as the outside pressure falls**.

Problem 13 Spot the error

The student used Celsius temperatures. $T_1 = 293 \text{ K}$, $T_2 = 353 \text{ K}$.

$$p_2 = 120 \times 353 / 293 = 144.6 = \mathbf{145 \text{ kPa}} \text{ (3 s.f.)}$$

Problem 14 Units first

1. $800 \text{ cm}^3 = \mathbf{0.80 \text{ L}}$

2. $100 \text{ kPa} = 100\,000 \text{ Pa} = 1.0 \times 10^5 \text{ Pa}$

3. $p_2 = 100 \times 0.80 / 0.50 = \mathbf{160 \text{ kPa}}$

Problem 15 Force on a piston

$$F = p A = 200\,000 \times 0.0030 = \mathbf{600\,N}$$

Problem 16 Pumping a bicycle tyre

Total air at 100 kPa = $1.5 + 6 \times 0.50 = 4.5$ L. This is squeezed into 1.5 L.

$$p_2 = 100 \times 4.5 / 1.5 = \mathbf{300\,kPa}$$

Problem 17 Rising bubble

1. $V_2 = 300 \times 5.0 / 100 = \mathbf{15\,cm^3}$

2. The air in the lungs expands as the outside pressure falls, here by a factor of three. If the breath is held, the lungs overstretch and can be damaged.

Problem 18 Extrapolating to absolute zero

1. At 0 °C, $T = 273$ K: $100 / 273 = 0.366$ kPa/K. At 100 °C, $T = 373$ K: $136.6 / 373 = 0.366$ kPa/K. The ratios are equal.

2. The dashed line reaches zero at **-273 °C**. This is absolute zero: the particles have minimum energy so they exert no pressure.

Problem 19 Jar in the freezer

1. $T_1 = 300$ K, $T_2 = 255$ K; $p_2 = 100 \times 255 / 300 = \mathbf{85\,kPa}$

2. Pressure difference = $100 - 85 = 15$ kPa = 15 000 Pa. $F = p A = 15\,000 \times 6.0 \times 10^{-4} = \mathbf{9.0\,N}$, pushing the lid inwards.

Problem 20 Compress then heat

Step 1 (Boyle): $p = 100 \times 3.0 / 1.0 = 300$ kPa at 300 K.

Step 2 (constant volume): $p_2 = 300 \times 450 / 300 = \mathbf{450\,kPa}$