

Gas particles, pressure and heat conduction

AP Physics 2 (algebra-based) · Worksheet

Name: _____ Date: _____ Class: _____

These twenty problems train the ideas of AP Physics 2 unit 9: kinetic theory, the ideal gas law and heat conduction. They run from conversions and one-step calculations to multi-step reasoning, graph analysis and an experimental design task.

Use kelvin for every gas calculation and SI units throughout. AP-style problems ask you to justify claims in words as well as numbers, so write a sentence of reasoning whenever the problem says explain.

Level: AP Physics 2 (algebra-based) · **Curriculum:** AP P2 Unit 9

Problem 1 Kelvin readings (easy)

Aarav in Pune reads three temperatures.

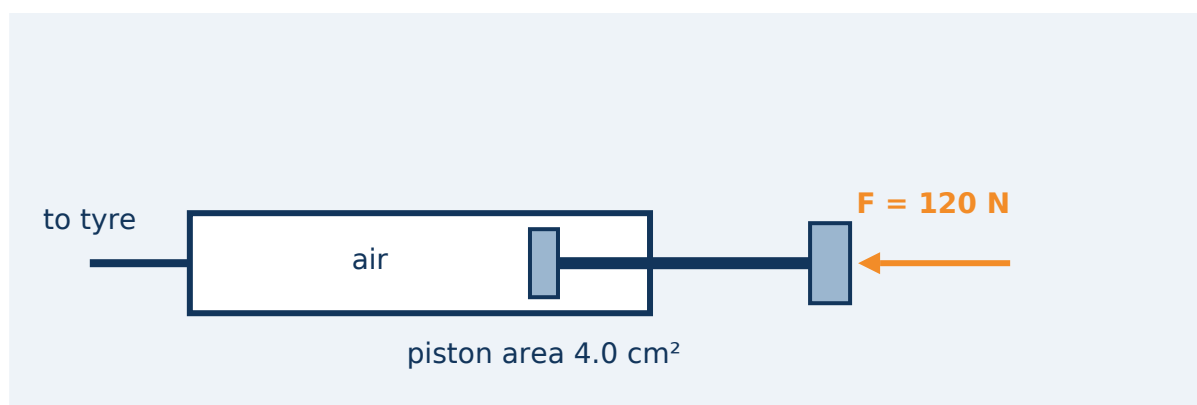
1. Convert 12 °C to kelvin.
2. Convert 400 K to degrees Celsius.
3. State the temperature of absolute zero in degrees Celsius.

Problem 2 Counting molecules (easy)

Chiamaka in Lagos fills a bottle with 0.25 mol of nitrogen, N₂ (molar mass 28 g/mol).

1. Calculate the number of molecules ($N_A = 6.02 \times 10^{23} \text{ mol}^{-1}$).
2. Calculate the mass of the gas in grams.

Problem 3 A bicycle pump (easy)



Hand pump, drawn schematically.

A pump piston of area 4.0 cm² is pushed with a force of 120 N, as shown.

1. Convert the area to m².

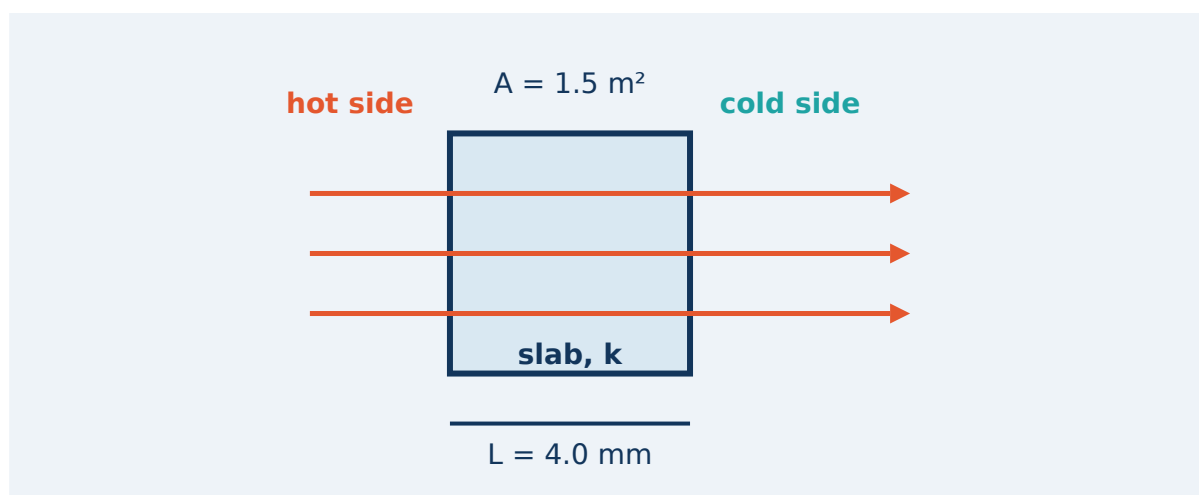
2. Calculate the pressure the piston exerts on the air.
3. Explain, in terms of particles, why the pressure rises as the air is squeezed.

Problem 4 Energy of one particle (easy)

A gas in a cylinder is at 27 °C.

1. Convert the temperature to kelvin.
2. Calculate the average kinetic energy of one particle ($k_B = 1.38 \times 10^{-23}$ J/K).
3. Calculate the average kinetic energy at 327 °C and compare it with part 2.

Problem 5 Heat through a window (easy)



Heat flows from the hot face to the cold face; the rate depends on k , A , the temperature difference and L .

A single glass window has $k = 0.80$ W/(m·K), area 1.5 m² and thickness 4.0 mm. The temperature difference between its faces is 12 K.

1. Convert the thickness to metres.
2. Calculate the rate of heat flow through the glass.
3. State what happens to the rate if the thickness is doubled.

Problem 6 Pressure from a particle count (medium)

A sealed 1.5 L flask holds 3.0×10^{22} molecules of gas at 310 K.

1. Convert the volume to m³.
2. Calculate the pressure with $p = Nk_B T/V$.
3. Compare the result with atmospheric pressure, 1.01×10^5 Pa.

Problem 7 Weather balloon (medium)

A weather balloon released in Leeds has a volume of 2.0 m³ at 1.01×10^5 Pa and 288 K. High in the atmosphere the pressure is 2.6×10^4 Pa and the temperature is 223 K.

1. Write the relationship that links the two states.
2. Calculate the new volume.
3. Explain why the balloon swells.

Problem 8 Speed of nitrogen (medium)

Mei in Singapore models the air in a lab at 293 K. Nitrogen molecules have molar mass 0.028 kg/mol.

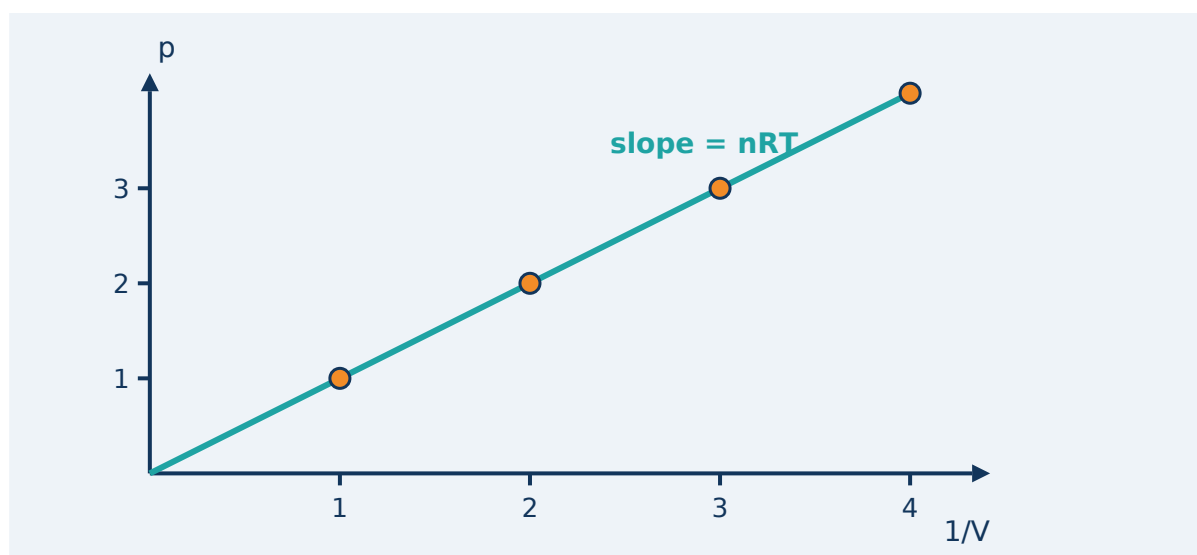
1. Calculate the root-mean-square speed.
2. Calculate the mass of one N_2 molecule using $m = M/N_A$.
3. Use your mass in $v_{rms} = \sqrt{3k_B T/m}$ to confirm part 1.

Problem 9 Doubling the speed (medium)

Nitrogen gas ($M = 0.028$ kg/mol) is cooled from 1000 K to 250 K.

1. Calculate v_{rms} at each temperature.
2. Find the ratio of the two speeds.
3. State the factor by which the kelvin temperature must change to double v_{rms} , and justify it.

Problem 10 Graph of p against 1/V (medium)



Data from a slow compression at 295 K.

A student compresses a trapped gas at a steady 295 K and finds that the product pV stays at 60.0 J.

1. State what the graph of p against $1/V$ looks like and what its slope equals.
2. Calculate the amount of gas in moles.
3. Calculate the pressure when the volume is $1.20 \times 10^{-3} \text{ m}^3$.

Problem 11 Heat through a brick wall (medium)

Bilal in Lahore studies a brick wall of area 12 m^2 and thickness 0.22 m , with $k = 0.72 \text{ W/(m}\cdot\text{K)}$. The inside face is at 21°C and the outside face at 5°C .

1. Calculate the temperature difference in kelvin.
2. Calculate the rate of heat loss.
3. Calculate the energy lost in one hour.

Problem 12 Pan bases compared (medium)

Two pans have bases of area 0.030 m^2 and thickness 3.0 mm . One is aluminium ($k = 205 \text{ W/(m}\cdot\text{K)}$) and the other stainless steel ($k = 16 \text{ W/(m}\cdot\text{K)}$). The temperature difference across each base is 4.0 K .

1. Calculate the heat flow rate through each base.
2. Find the ratio of the two rates.
3. Explain why a steel pan with a copper layer is sold for even heating.

Problem 13 Sealed can on a stove (medium)

Emma in Leeds accidentally leaves a sealed metal can of air on a hot plate.

1. Describe what happens to the speeds of the air particles.
2. Explain, using collisions, why the pressure inside rises.
3. State why the can might burst even though no gas has been added.

Problem 14 Helium against air (medium)

Kofi in Accra fills a balloon with helium ($M = 0.0040 \text{ kg/mol}$) at $1.01 \times 10^5 \text{ Pa}$ and 293 K . Air has $M = 0.0290 \text{ kg/mol}$.

1. Show that $\rho = pM/(RT)$ for an ideal gas.
2. Calculate the density of helium and of air under these conditions.
3. Calculate the net upward force on 1.0 m^3 of helium, meaning the buoyant force minus the weight of the helium.

Problem 15 Spot the error (medium)

A student calculates the pressure of 0.15 mol of gas in a 3.0 L container at 25°C : $p = (0.15 \times 8.31 \times 25)/3.0 = 10.4 \text{ Pa}$.

1. Identify two errors.
2. Calculate the correct pressure.
3. Explain why the student's answer is physically unreasonable.

Problem 16 A heated jar lid (hard)

A jar of air is sealed at 20°C (293 K) and $1.00 \times 10^5 \text{ Pa}$, then heated to 180°C (453 K). The lid has area $5.0 \times 10^{-3} \text{ m}^2$ and the pressure outside stays at $1.00 \times 10^5 \text{ Pa}$. Assume the jar volume is constant.

1. Calculate the pressure inside at 180°C .
2. Calculate the net outward force on the lid.
3. Describe what the lid does if its seal can hold only 200 N .

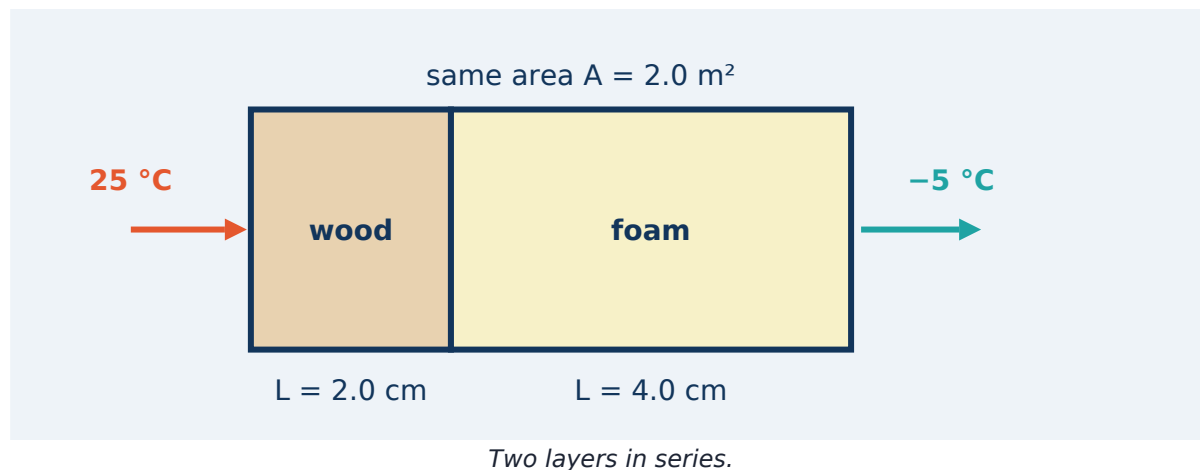
Problem 17 Bubble from a lake bed (hard)

A bubble of volume 1.0 cm^3 forms at the bottom of a lake 12 m deep, where the

temperature is 280 K. It rises to the surface where the temperature is 295 K. Take the water density as 1000 kg/m^3 , $g = 9.81 \text{ N/kg}$ and the pressure at the surface as $1.01 \times 10^5 \text{ Pa}$.

1. Calculate the pressure at the bottom.
2. Calculate the volume of the bubble at the surface.
3. Explain which change, pressure or temperature, has the bigger effect.

Problem 18 Two layers in series (hard)



A wall is made of a wooden layer ($k = 0.15 \text{ W/(m}\cdot\text{K)}$, thickness 2.0 cm) and a foam layer ($k = 0.030 \text{ W/(m}\cdot\text{K)}$, thickness 4.0 cm), both of area 2.0 m^2 . The outer faces are at 25 °C and -5 °C . In steady state the heat flow is the same through both layers.

1. Calculate $L/(kA)$ for each layer.
2. Calculate the heat flow rate.
3. Calculate the temperature at the wood-foam interface.

Problem 19 Heavier means faster? (hard)

A student argues: oxygen molecules are heavier than nitrogen molecules, so at 300 K they carry more kinetic energy and move faster. Oxygen has $M = 0.032 \text{ kg/mol}$ and nitrogen has $M = 0.028 \text{ kg/mol}$.

1. Compare the average kinetic energies of the two gases at 300 K.
2. Calculate the ratio $v_{\text{rms}}(\text{O}_2)/v_{\text{rms}}(\text{N}_2)$.
3. Write a short paragraph correcting the student's argument.

Problem 20 Design an experiment on conduction (hard)

Design an investigation of how the rate of heat conduction along a metal rod depends on the rod's length. Your answer must include:

1. The independent, dependent and controlled variables.
2. The equipment and a short method.
3. The graph you would plot and the shape the theory predicts.