Topic 5: Solids, liquids and gases

Edexcel International GCSE Physics 4PH1 · Section 5 · statements 5.1–5.22 · sheets 5.1–5.2

Why skis and not shoes?

Your turn

A student walks across deep snow, first in shoes and then on skis.

A. Does the student's weight change?

B. What changes, and why does the student sink less on skis?

C. Predict the pressure under a sharp knife edge.

Three equations for density and pressure

$$\rho = \frac{m}{V} \qquad p = \frac{F}{A} \qquad p = h \times \rho \times g$$

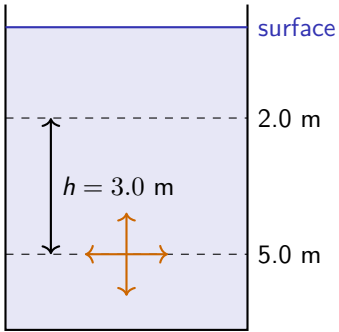
ρ in kg/m^3, p in Pa (N/m^2), A in m^2, h depth difference in m

1. **Known** Stone: mass 54 g; water level rises from 50.0 cm^3 to 70.0 cm^3.
2. **Volume** By displacement: $V = 70.0 - 50.0 = 20.0$ cm^3.
3. **Density** $\rho = m/V = 54\ \text{g}/20.0\ \text{cm}^3 = 2.7$ g/cm^3.
4. **Units** Multiply by 1000: 2700 kg/m^3.

Pressure on an area

1. **Known** Weight 600 N; two feet have total area 0.040 m^2.
2. **Equation** Pressure is force per unit area: $p = F/A$.
3. **Feet** $p = 600\ \mathrm{N}/0.040\ \mathrm{m}^2 = 15\,000$ Pa.
4. **Skis** Area 0.40 m^2: $p = 600/0.40 = 1500$ Pa, so the student does not sink.

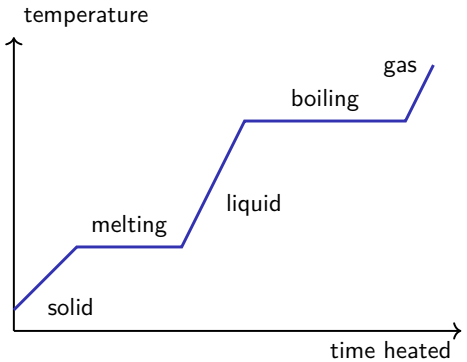
Pressure in a fluid grows with depth



Between 2.0 m and 5.0 m deep in water:
$p = 3.0 \times 1000 \times 10 = 30\,000$ Pa.

- Fluid pressure acts equally in all directions.
- Use the difference in depth.

(P) Heating curve and change of state



On a plateau the energy breaks bonds between particles, so the temperature stays constant.

- Flat sections are melting and boiling.
- Energy breaks bonds; temperature stays constant.

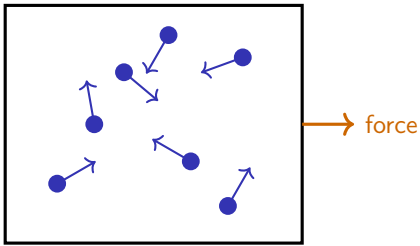
(P) Specific heat capacity

$$\Delta Q = m \times c \times \Delta T$$

c in J/(kg °C); water c = 4200 J/(kg °C)

1. **Known** 0.50 kg of water from 20 °C to 80 °C.
2. **Change** $\Delta T = 80 - 20 = 60$ °C.
3. **Substitute** $\Delta Q = 0.50\ \text{kg} \times 4200\ \text{J/(kg °C)} \times 60\ \text{°C} = 126\,000$ J.
4. **Trap** Using 80 °C as ΔT is the most common slip.

Gas pressure comes from collisions



Each collision pushes on the wall; the total force per unit area is the pressure.

- Molecules move randomly and hit the walls.
- **Absolute zero** is $-273\ ^\circ\text{C}$; $\text{K} = {}^\circ\text{C} + 273$.

Two gas laws for a fixed mass

$$p_1 V_1 = p_2 V_2 \qquad \frac{p_1}{T_1} = \frac{p_2}{T_2}$$

T always in kelvin

Squeeze it (constant T)

Molecules hit the walls more often.

$p_2 = 100\ \text{kPa} \times 2/0.5 = 400\ \text{kPa}$.

Heat it (constant V)

Faster molecules hit harder and more often.

$p_2 = 100\ \text{kPa} \times 450/300 = 150\ \text{kPa}$.

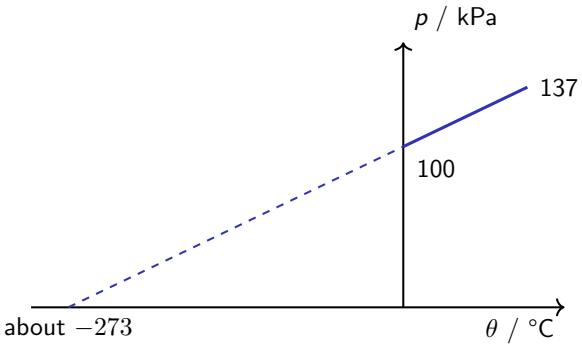
Worked example: convert to kelvin first

1. **Known** Tyre at 200 kPa and 27 °C; after driving, 57 °C; same volume.
2. **Kelvin** $T_1 = 27 + 273 = 300$ K; $T_2 = 57 + 273 = 330$ K.
3. **Equation** $p_1/T_1 = p_2/T_2$, so $p_2 = p_1 T_2/T_1$.
4. **Substitute** $p_2 = 200\ \text{kPa} \times 330\ \text{K}/300\ \text{K} = 220$ kPa.

Decision

With °C you would get 422 kPa: more than double for a 30 °C rise, clearly wrong.

Extrapolate to absolute zero



Gradient 0.37 kPa per °C; to lose 100 kPa needs about 270 °C less: near −273 °C.

- The line meets p = 0 near −273 °C.
- p ∝ T only in kelvin.

Six mistakes that cost marks

Mistake	**Correct idea**
g/cm^3 in $p = h\rho g$	Use kg/m^3; 1 g/cm^3 = 1000 kg/m^3
Area in cm^2	50 cm^2 = 0.0050 m^2
°C in the gas laws	K = °C + 273
Final temperature as ΔT	Subtract the start temperature
Temperature rises while melting	It stays constant; bonds break
Heated gas molecules get bigger	They move faster and hit harder

Check yourself

Your turn

Answer without notes, then check.

A. A 240 g block has volume 40 cm^3. Density in kg/m^3?

B. Pressure under a 500 N heel of area 0.01 m^2?

C. (P) Energy to heat 0.5 kg of aluminium ($c = 900$) by 40 °C?

D. Convert 27 °C to kelvin, and 373 K to °C.

E. Why does a gas exert pressure on its container?