# A Level OCR Physics

## Chapter 15 Thermal physics

| Question | Answers | Extra information | Mark | AO | Spec reference |
|---|---|---|---|---|---|
| **1 (a)** | Any two from:<br>1. A gas consists of molecules of negligible volume.<br>2. The molecules collide elastically with each other and the container, thus gaining or losing no energy.<br>3. There are negligible forces of attraction between the molecules.<br>4. The duration of an impact is much less than the time between impacts. | | 1 | 1 | 5.1.4 |
| **(b) (i)** | $pV = nRT$, $p_1V_1 = p_2V_2$<br>$V_2 = p_1V_1/p_2$<br>$= 101\,000 \times 3.51/2.1\times10^6$<br>$= 0.131\ \text{m}^3 = 0.13\ \text{m}^3$<br>Assuming there is no change to the temperature or number of mols of gas | Use of ideal gas equation by finding $nRT$ or ratios<br>answer | 1<br>1 | 2 | 5.1.4 |
| **(ii)** | Example:<br>The molecules do not have negligible volume, they have a finite volume. The actual volume is less than that given, so the pressure will be higher. | Suggestion linked to kinetic theory/ideal gas assumptions<br>Correct reasoning/effect on pressure | 1<br>1 | 1 | 5.1.4 |
| **(iii)** | $T$ (K) = $T$ (°C) + 273 = 293 K | Temperature in K | 1 | | 5.1.1 |
| **(iv)** | Number of mols = $pV/RT$<br>$101\,000 \times 4.83/(8.31 \times 293) = 200.4$ mols<br>Mass of gas = $200.4 \times 6.02\times10^{23} \times 7.32\times10^{-26}$<br>= 8.83 kg<br>$E = mL$, $L = E/m = 1.31\times10^6/8.83 = 148\ \text{kJ kg}^{-1}$ | Number of mols<br>Mass of gas<br>answer | 1<br>1<br>1 | 3 | 5.1.3 |
| **2 (a)** | $E$ water = $mc\Delta\theta = 1.62 \times 4200 \times (100 - 20) = 544\,320$ J, $= 5.4\times10^5$ J = 540 kJ<br>$E$ pan = $mc\Delta\theta = 0.75 \times 385 \times (100 - 20) = 23\,408$ J, $= 2.3\times10^4$ J = 23 kJ | Calculations of energy | 1<br>1 | 2 | 5.1.3 |

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| | Total energy = $5.67\times10^5$ J<br>Power = energy/time = $5.67\times10^5$ J/10 × 60 = 946 W ≈ 950 W<br>Assuming room temperature is 20 °C | Answer including assumption | 1 | | |
| (b) | Assuming the energy is transferred so that the water and potatoes are at the same temperature, and no energy is transferred to the surroundings<br>Energy transferred from water = 1.62 × 4200 × 14 = 95 256 J<br>Assuming the potatoes are heated to the same temperature as the water<br>95 256 = mass × 3390 (86 – 20)<br>Mass = 0.43 kg. | Assumptions that potatoes at the same temperature<br>Answer | 1<br>1 | 2 | 5.1.3 |
| (c) | Internal energy is the sum of the randomly distributed kinetic energies and potential energies of the particles in a body<br>The water will start to evaporate, so energy will be used to break the bonds/increase the potential energy of the particles without changing their speed/increasing the kinetic energy of the particles. | Description/definition of internal energy<br>Effect of evaporation on time | 1<br>1 | 2 | 5.1.3 |
| (d) | Assume temperature difference is the same = 80 °C<br>Power = energy per second = mass per second × $c$ × $\Delta\theta$<br>mass per second = $P/c$ × $\Delta\theta$ = 946/4200 × 80 = $2.82\times10^{-3}$ kg $s^{-1}$.<br>Time to fill the pan with 1.62 kg of water = $1.62/2.82\times10^{-3}$ = 575 s = 5 mins 35 s.<br>This is a long time, so not appropriate for filling pans, better for filling cups/ original power calculation involved heating the pan so this time would be shorter as power would be greater. | Calculation of mass per second<br>Allow use of 950 W and 544 320 J from (a)<br>Answer<br>Suitable comment | 1<br>1 | 3 | 5.1.3 |
| 3 (a) | The temperature at which the internal energy/pressure is zero | | 1 | 1 | 5.1.2 |
| (b) | Temperature, volume, number of mols (molecules)/mass of gas | Do not accept ‘amount of gas’<br>Do not accept ideal gas equation without names of quantities | 1 | | 5.1.4 |

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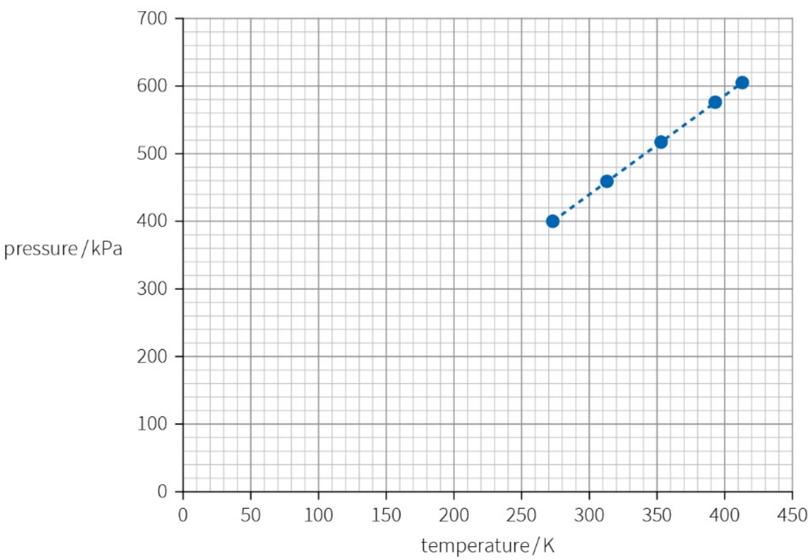
<table>
<tr><th>Question</th><th>Answers</th><th>Extra information</th><th>Mark</th><th>AO</th><th>Spec reference</th></tr>
<tr><td>(c) (i)</td><td>To find relationship between temperature and pressure you need the volume to be constant<br>There is the greatest number of data points for 10 cm<sup></sup>$^3$.<br>

<table>
<tr><th>$T$ (C)</th><th>$T$ (K)</th><th>$p$ (kPa)</th></tr>
<tr><td>273</td><td>0</td><td>400</td></tr>
<tr><td>313</td><td>40</td><td>459</td></tr>
<tr><td>353</td><td>80</td><td>517</td></tr>
<tr><td>393</td><td>120</td><td>576</td></tr>
<tr><td>413</td><td>160</td><td>605</td></tr>
</table>



</td><td>Using the data for 10 cm$^3$<br>Reason given<br>Appropriate graph of $P$ vs. $T$, with appropriate axes<br>Points plotted, line of best fit</td><td>1<br>1<br>1<br>1</td><td></td><td>5.1.4</td></tr>
<tr><td>(ii)</td><td>$pV = nRT$, so gradient = $nR/V$</td><td>Correctly identifying gradient = $nR/V$</td><td>1</td><td></td><td>5.1.4</td></tr>
</table>

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| | Gradient = (600 − 400) × 1000/(413 − 273) = 1429<br>$nR/V$ = 1429<br>$n$ = 1429 × 10 ×$10^{-6}$/8.31<br>= 0.0017 mol<br>The pressure is proportion to the temperature, not inversely proportional, as suggested. | *Allow range of gradients from 1350 – 1500*<br>Use of gradient to find number of mols<br>Comment about prediction justified by graph | 1<br>1 | | |
| **(d)** | If the density doubles the number of particles in a given volume doubles<br>The number of collisions would double, as would the force, and hence pressure<br>However, if the density is very high the gas may not behave like an ideal gas because the particles are too close together/take up too much volume/interact. | Justification based on ratios/proportion<br>With appropriate qualification | 1<br>1 | | 5.1.4 |
| **4 (a)** | Sample method:<br>• Measure the diameter of the plunger of a plastic syringe, and calculate the cross-sectional area.<br>• Draw in 4.0 $cm^3$ of air into the syringe and clamp it in a stand.<br>• Attach 100 g to the plunger, making sure the plunger can move downwards freely. Record the volume of gas in the syringe by estimating fractions of a division.<br>• Repeat the procedure with an extra two 100 g masses added to the holder each time, up to a total mass of 1000 g.<br>• The whole experiment should then be repeated to obtain a second set of results, and the mean volumes found.<br>• The force exerted by the masses can be calculated using $F = mg$ where $m$ is the mass in kg and $g$, the gravitational field strength, is 9.81 N $kg^{-1}$.<br>• The pressure exerted by this force on the air sample is then $F/A$ in Pascals (Pa). Convert this into kPa. | Measurements to find force, area, volume<br>Calculation of pressure<br>Repetition, finding mean,<br>Subtraction of atmospheric pressure | 4 | | 5.1.4 |

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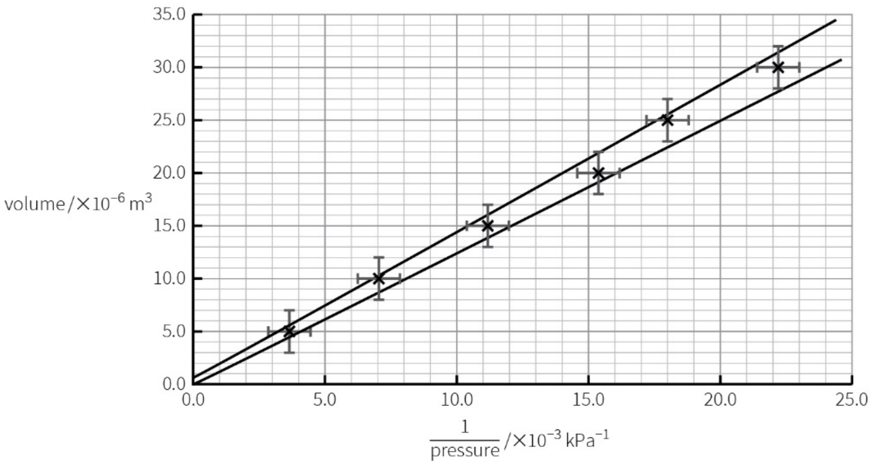
| | This should be subtracted from standard atmospheric pressure, 101 kPa, to obtain the pressure of the air sample, *P*. (Note: the initial volume of the air with no masses hung on the loop will be at standard atmospheric pressure.) | | | | |
| **(b) (i)** | If the pressure is inversely proportional to volume then a graph of $1/p$ against $V$ will be a straight line through (0,0)<br>Missing value is $1/(90 \times 10^3) = 11.1\times10^{-6}$. | | 1<br>1 | | 5.1.4 |
| **(ii)** | <br>Point plotted, correct labels on axes, two lines showing a range of gradients<br>Upper graph: Gradient = 30 – 0 / 20.1 – 0 = 1.49 ($\times10^{-6}$ m$^3$/$\times10^{-3}$ kPa$^{-1}$) = $1.49\times10^{-6}$ m$^3$ kPa$^{-1}$<br>Lower graph: Gradient = 30 – 0 / 24.0 – 0 = 1.25 ($\times10^{-6}$ m$^3$/$\times10^{-3}$ kPa$^{-1}$) = $1.25\times10^{-6}$ m$^3$ kPa$^{-1}$<br>$pV = nRT$, so graph of $V$ vs $1/p$ has a gradient of $nRT$, where $T = 273 + 21.0 = 294$ K<br>Upper graph: number of mols = gradient/$RT$ = $1.49\times10^{-6}$ / (8.31 × 294) = $6.10\times10^{-4}$<br>Lower graph: number of mols = gradient/$RT$ = $1.25\times10^{-6}$ / (8.31 × 294) = | Graph finished correctly<br>Two gradients calculated<br>Calculation of number of mols for each gradient, and mean | 1<br>1<br>1 | | 5.1.4 |

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| | $5.12\times10^{-4}$<br>Average number = $(6.10 \times 10^{-4} + 5.12 \times 10^{-4})/2 = 5.61\times10^{-4}$<br>Number with uncertainty = $(5.61 \pm 0.51)\times10^{-4}$ | Answer with uncertainties | 1 | | |
| **(iii)** | Error bars are appropriate for volume measurement as the uncertainty in reading the volume using the scale on the syringe is going to be the same each time<br>uncertainty in the pressure depends on the uncertainties in the measurement of the diameter, which is the same for each, but also in the uncertainty in the masses, which is different. | Comment that bars for *V* should be the same, but for 1/*p* will be different | 1<br>1 | | 5.1.4 |
| **5 (a) (i)** | **Level 3 (5–6 marks)** Multiple comparisons for both similarities and differences<br>*The student presents relevant information coherently, employing structure, style and SP&G to render meaning clear.*<br><br>**Level 2 (3–4 marks)** Comparisons of both similarities and differences but with some misunderstanding or limited comparisons.<br>*The student presents relevant information and in a way which assists the communication of meaning. SP&G are sufficiently accurate not to obscure meaning.*<br><br>**Level 1 (1–2 marks)** Limited comparison between the 2 methods with only similarities or differences described<br>*The student presents some relevant information in a simple form. SP&G allow meaning to be derived although errors are sometimes obstructive.*<br><br>0 marks No response or no response worthy of credit. | **Indicative scientific points may include:**<br><br>Similarities in methods:<br>- Electric heater used to heat a known mass of liquid<br>- Insulated container for liquid<br>- pd., current and time measured<br><br>Differences in methods:<br>- SHC container has a lid, but for SLH does not<br>- Temperature change is measured for SHC, change in mass is measured for SLH<br>- Equations quoted for both | 6 | 3 | 5.1.2 |
| **(ii)** | In the SHC experiment the average speed of the molecules increases, so the internal energy increases because of an increase of kinetic energy of the | | 1 | 2 | 5.1.2 |

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| | molecules<br>In the SLH the internal energy increases because the potential energy of the molecules increases. | | 1 | | |
| **(b) (i)** | Bright dots of light, which are smoke particles, moving randomly in Brownian motion<br>Because they are being bombarded by gas molecules of the air. | Description separate from explanation | 1<br>1 | 1 | 5.1.2 |
| **(ii)** | They would see bright spots that would move less/vibrate<br>Water molecules are touching/not moving around. | | 1<br>1 | 3 | 5.1.2 |
| **6 (a) (i)** | Change in momentum = $(mv_1) - (-mv_2)$ = $4.6\times10^{-26}$ (510 – (–510)) = $4.69\times10^{-23}$ kg m s$^{-1}$<br>Time between collisions = $d/v$ = 0.3/510 = 5.9 (5.88)$\times10^{-4}$ s | Answer<br>Answer | 1<br>1 | 2 | 3.5.1 |
| **(ii)** | Force = rate of change of momentum<br>= $4.69\times10^{-23}/5.88\times10^{-4}$ = $7.97\times10^{-20}$ N<br>Pressure = force/area<br>= $7.97\times10^{-20}/(0.3 \times 0.3)$ = $8.86\times10^{-19}$ Pa | Use of $F = \frac{dmv}{dt}$<br>Answer | 1<br>1 | 2 | 3.5.1 |
| **(iii)** | Number of gas molecules = 100 000/$8.86\times10^{-19}$<br>= $1.13\times10^{23}$<br>Number of mols = $1.13\times10^{23}/6.02\times10^{23}$<br>= 0.19 (0.187) mols | Answer | 1 | 2 | 6.1.4 |
| **(b)** | $\frac{3}{2}kT = \frac{1}{3}mc^2$<br>$T = \frac{2}{9}\frac{m}{k}c^2 = \frac{2}{9}\frac{4.6 \times 10^{-26}}{1.38 \times 10^{-23}} \times 510^2 = 193$ K<br>$pV = nRT$ | Two temperatures calculated<br>Reasoning to conclusion that number | 1<br>1 | 3 | 5.1.4 |

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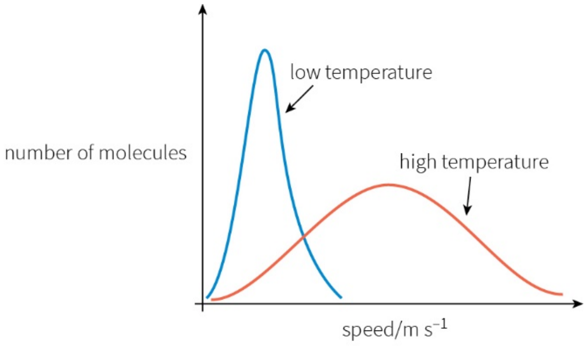
| | $T = \frac{pV}{nR} = \frac{100\,000 \times (0.3)^3}{0.187 \times 8.31} = 1737$ K<br>Any 2 from<br>- The temperature suggested by the ideal gas equation is much higher, so the assumptions in the derivation of the number of mols must have produced a number that is too low<br>- The molecules do not all hit the surface at 90°, so the average change in momentum will be smaller<br>- They will collide with other molecules so the time between collisions will be bigger<br>- The force exerted will be much smaller as $F = \frac{dmv}{dt}$, so the number of mols of gas to produce the same pressure must be much larger. | of mols is larger to include:<br>- angles<br>- force<br>- time | 1<br>1 | | |
| **7 (a)** |  | Low temperature peaks at lower speed<br>Higher temperature peak lower<br>Correct shape by eye + axes labelled | 1<br>1<br>1 | | 5.1.4 |
| **(b)** | Mean mass of air molecule = $28.97\times10^{-3}/6.02\times10^{23}$<br>$= 4.8\times10^{-26}$ kg<br>$\frac{1}{2}mc^2 = \frac{3}{2}kT$ | Calculation of mass<br>Calculation | 1<br>1 | | 5.1.4 |

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| | $\sqrt{c^2} = \sqrt{\frac{3kT}{m}} = \sqrt{\frac{3 \times 1.38 \times 10^{-23} \times (22.4 + 273.14)}{4.8 \times 10^{-26}}}$<br>$= 504\ \text{m s}^{-1}$ | Answer | 1 | | |
| (c) (i) | $E_{\text{grav}} = -\frac{GMm}{r}$ = energy of a mass $m$ at a distance $r$ from a mass $M$<br>Assuming that the velocity of an object is zero at infinity<br>$\frac{1}{2}mv^2 + -\frac{GMm}{r} = 0$<br>$\frac{1}{2}mv^2 = \frac{GMm}{r}$<br>$v = \sqrt{\frac{2GM}{r}}$ | Use of equation for EPE<br>Manipulation | 1<br>1 | | 5.4.4 |
| (ii) | Earth:<br>$v_{\text{escape}} = (2 \times 6.67{\times}10^{-11}\ \text{N m}^2\ \text{kg}^{-3} \times 5.97{\times}10^{24}\ \text{kg} / 6.378{\times}10^{6}\ \text{m})^{0.5}$<br>$v_{\text{escape}} = 1.12{\times}10^{4}\ \text{m s}^{-1} = 11.2\ \text{km s}^{-1}$,<br>which is about 22 times the average speed of molecule of the atmosphere, so the gas molecules are not travelling fast enough to escape.<br>The escape velocity of the Moon is only about 5 times greater than the average velocity of a gas molecule at 22.4°C.<br>The temperature of the Moon can be about 4 times greater, which would double the average velocity.<br>There would be molecules in the distribution travelling fast enough to escape. | Answer<br>Comparison with mean speed<br>Comparison with mean speed<br>Effect of temperature on speed<br>Use of distribution | 1<br>1<br>1<br>1<br>1 | | 5.1.4 |

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| **8 (a)** | Energy transferred/sec = mass/s. $c$. $\Delta\theta$<br>= density × vol/s. $c$. $\Delta\theta$<br>= 997 × 2.7×10$^{-3}$ × 4200 × (45 – 34)<br>= 1.24 ×10$^{5}$ J s$^{-1}$ | Use of equation for SHG and density<br>answer | 1<br>1 | | 5.1.3 |
| **(b)** | $\Delta\theta$ = Energy transferred/sec/ density × vol/s. $c$<br>= 1.24×10$^{5}$/(1.225 × 2.2 × 1000)<br>= 46 °C<br>Temperature of the air leaving = 16 + 46 = 62 °C<br>Assuming all the energy transferred from the water is transferred to the air. | Calculation to find temperature difference<br>Answer<br>Assumption | 1<br>1<br>1 | | 5.1.3 |
| **(c)** | Energy is transferred to the material of the pipe, casing of the heater/the air is not heated completely because of convection | | 1 | | 5.1.1 |
| **(d)** | A current flows in a coil inside the motor which is in a magnetic field<br>There is a force on each side of the coil causing it to spin. | | 2 | | 6.3.1 |
| **(e)** | The coil is a conductor in a magnetic field, so an emf is induced in it when it spins<br>The direction of the emf is in a direction so as to oppose the motion that caused it, so produces an emf that reduces the current (Lenz's law) | | 1<br>1 | | 6.3.1 |

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