A Level AQA Physics

13 Thermal physics – answers

Question	Answers	Extra information	Mark	AO	Spec reference
01.1	Any two from: • A gas consists of molecules of negligible size • The molecules collide elastically with each other and the container, thus gaining or losing no energy • The molecules are in continual random motion • There are negligible forces of attraction between the molecules • The duration of an impact is much less than the time between impacts		1 1	1	3.6.2.3
01.2	$pV = nRT, p_1V_1 = p_2V_2$ $V_2 = \frac{p_1V_1}{p_2}$ $= \frac{101\,000 \times 3.51}{2.1 \times 10^6}$ $= 0.169\ \text{m}^3 = 0.17\ \text{m}^3$ Assuming there is no change to the temperature or number of mols of gas	Use of ideal gas equation by finding nRT or ratios answer	1 1	2	3.6.2.2
01.3	Example: 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 Correct reasoning/effect on pressure	1 1	3	3.6.2.3
01.4	Number of mols $= \frac{pV}{RT}$ $\frac{101\,000 \times 3.51}{8.31 \times 293} = 145.5$ mols Mass of gas $= 145.5 \times 6 \times 10^{23} \times 7.32 \times 10^{-26}$ $= 6.41$ kg $E = ML, L = \frac{E}{M} = \frac{1.31 \times 10^6}{6.41} = 204\ \text{kJ kg}^{-1}$	Number of mols Mass of gas answer	1 1 1	2	3.6.2.2

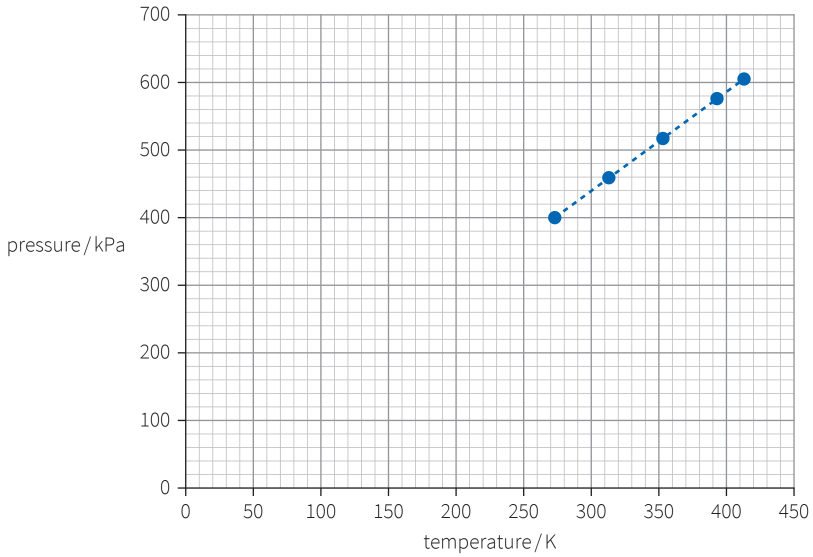
A Level AQA Physics

13 Thermal physics – answers

Question	Answers	Extra information	Mark	AO	Spec reference
02.1	$E_{water} = mc\Delta T = 1.45 \times 4200 \times (100 - 20) = 487\,200\text{ J} = 4.9\times10^5\text{ J} = 490\text{ kJ}$ $E_{pan} = mc\Delta T = 0.8 \times 385 \times (100 - 20) = 24\,640\text{ J} = 2.5\times10^4\text{ J} = 25\text{ kJ}$ Total energy = 5.12×10^5 J Power = $\frac{\text{energy}}{\text{time}} = \frac{5.12\times10^5\text{ J}}{10 \times 60} = 853\text{ W} = 850\text{ W}$ no energy losses to the surroundings	Calculations of energy Answer including assumption	1 1	2	3.6.2.1
02.2	Assuming the energy is transferred so that the water and potatoes are at the same temperature, and no energy is transferred to the surroundings Energy transferred from water = $1.45 \times 4200 \times 14 = 85\,260$ J Assuming the potatoes are heated to the same temperature as the water $85\,260 = \text{mass} \times 3\,390 \times (86 - 20)$ Mass = 0.38(1) kg.	Assumptions that potatoes at the same temperature Answer	1 1	2	3.6.2.1
02.3	Internal energy is the sum of the randomly distributed kinetic energies and potential energies of the particles in a body 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 Effect of evaporation on time	1 1	3	3.6.2.1
02.4	temperature difference is the same = 80 °C Power = energy per second = mass per second $\times C \times \Delta T$ mass per second = $\frac{P}{C \times \Delta T} = \frac{853}{4200 \times 80} = 2.54\times10^{-3}\text{ kg s}^{-1}$ Time to fill the pan with 1.45 kg of water = $\frac{1.45}{2.54\times10^{-3}} = 571\text{ s} = 5\text{ mins }31\text{ s}$ 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 Answer Suitable comment	1 1	2	3.6.2.1
03.1	Temperature, volume, number of mols (molecules)/mass of gas	Do not accept 'amount of gas' Do not accept ideal gas equation without names of quantities	1	1	3.6.2.2

A Level AQA Physics

13 Thermal physics – answers

<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>03.2</td><td>To find relationship between temperature and pressure, you need the volume to be constant
There is the greatest number of data points for 10 cm^3
<table><tr><th>T / K</th><th>p / kPa</th></tr><tr><td>273</td><td>400</td></tr><tr><td>313</td><td>459</td></tr><tr><td>353</td><td>517</td></tr><tr><td>393</td><td>576</td></tr><tr><td>413</td><td>605</td></tr></table>

</td><td>Using the data for 10 cm^3

Reason given

Appropriate graph of p vs T, with appropriate axes

Points plotted, line of best fit</td><td>1

1

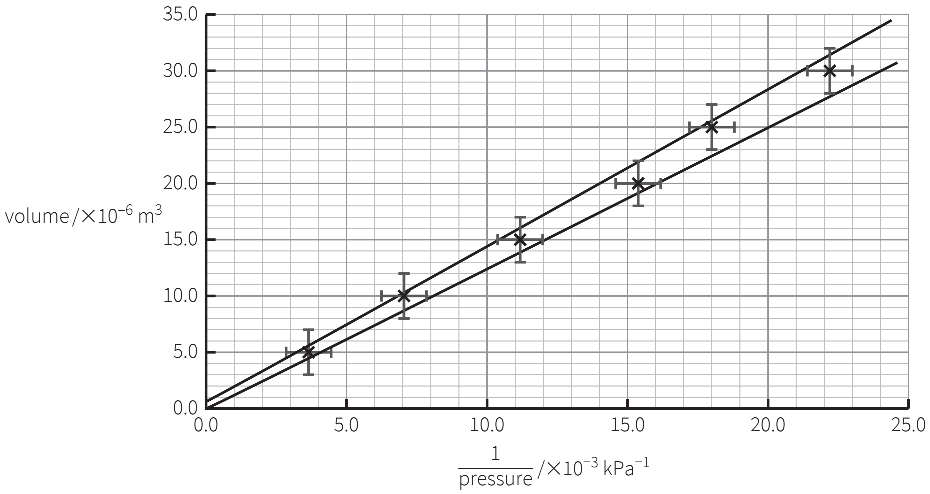
1

1</td><td>2</td><td>3.6.2.2</td></tr>
</table>

A Level AQA Physics

13 Thermal physics – answers

Question	Answers	Extra information	Mark	AO	Spec reference
03.3	$pV = nRT$, so gradient $= \frac{nR}{V}$ Gradient $= \frac{(600 - 400) \times 1000}{(413 - 273)} = 1429$ $\frac{nR}{V} = 1492$ $n = \frac{1492 \times 10 \times 10^{-6}}{8.31} = 0.0017$ mol The pressure is proportion to the temperature, not inversely proportional, as suggested	Correctly identifying gradient $= \frac{nR}{V}$ Use of gradient to find number of mols Comment about prediction justified by graph	1 1 1	2	3.6.2.2
03.4	If the density doubles, the number of particles in a given volume doubles The number of collisions would double, as would the force, and hence pressure 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 With appropriate qualification	1 1 1	3	3.6.2.2
04.1	Sample method: • Measure the diameter of the plunger of a plastic syringe and calculate the cross-sectional area • Draw in 4.0 cm^3 of air into the syringe and clamp it in a stand • 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 • Repeat the procedure with an extra two 100 g masses added to the holder each time, up to a total mass of 1000 g. • The whole experiment should then be repeated to obtain a second set of results, and the mean volumes found • 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}	Measurements to find force, area, volume Calculation of pressure Repetition, finding mean, Subtraction of atmospheric pressure	4	1	3.6.2.2

Question	Answers	Extra information	Mark	AO	Spec reference
	• The pressure exerted by this force on the air sample is then $\frac{F}{A}$ in pascals (Pa). Convert this into kPa 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)				
04.2	If the pressure is inversely proportional to volume, then a graph of $\frac{1}{p}$ against V will be a straight line through (0, 0) Missing value is $\frac{1}{90\times10^{3}} = 11.1\times10^{-3}$ so 11.1		1 1	2	3.6.2.2
04.3	 Point plotted, correct labels on axes, two lines showing a range of gradients Upper graph: Gradient = $\frac{30-0}{20.1-0} = 1.49 \times \left(\frac{10^{-6}\,m^3}{10^{-3}\,kPa^{-1}}\right) = 1.49 \times 10^{-6}\,m^3\,Pa^{-1}$	Graph finished correctly Two gradients calculated	1 1	2	3.6.2.2

Question	Answers	Extra information	Mark	AO	Spec reference
	Lower graph: Gradient = $\frac{30-0}{24.0-0} = 1.49 \times \left(\frac{10^{-6}\,m^3}{10^{-3}\,kPa^{-1}}\right) = 1.25 \times 10^{-6}\,m^3\,Pa^{-1}$ $pV = nRT$, so graph of V vs $\frac{1}{p}$ has a gradient of nRT, where $T = 273 + 21.0 = 294\,K$ Upper graph: number of mols = $\frac{gradient}{RT} = \frac{1.49 \times 10^{-6}}{8.31 \times 294} = 6.10 \times 10^{-4}$ Lower graph: number of mols = $\frac{gradient}{RT} = \frac{1.25 \times 10^{-6}}{8.31 \times 294} = 5.12 \times 10^{-4}$ Average number = $\frac{6.10 \times 10^{-4} + 5.12 \times 10^{-4}}{2} = 5.61 \times 10^{-4}$ Number with uncertainty = $(5.61 \pm 0.51) \times 10^{-4}$	Calculation of number of mols for each gradient, and mean Answer with uncertainties	1 1		
04.4	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, but the 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 $\frac{1}{p}$ will be different	1	3	3.6.2.2
05.1	Area under graph between A and B shaded Work done on the gas increases the internal energy, so the kinetic and potential energies of the molecules increase If the (average) kinetic energy increases that means that the gas has a higher temperature		1 1	2	3.6.2.2

A Level AQA Physics

13 Thermal physics – answers

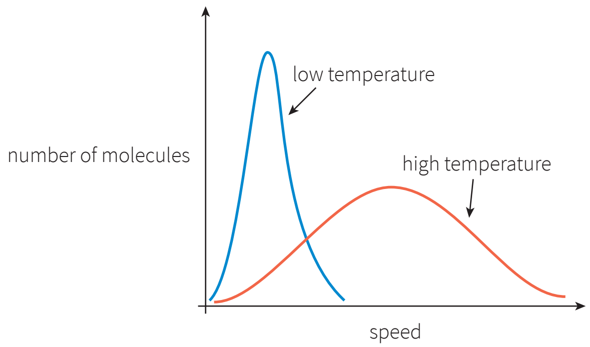
Question	Answers	Extra information	Mark	AO	Spec reference
05.2	$pV = NkT$ so $N = \frac{pV}{Tk}$ $= \frac{3.2\times10^{6} \times 195\times10^{-6}}{(450 + 273) \times 1.38\times10^{-23}} = 6.25 \times 10^{22}$ Or $pV = nRT$ so $n = \frac{pV}{RT}$ $= \frac{3.2\times10^{6} \times 195\times10^{-6}}{8.31 \times (450 + 273)}$ = 0.104 mols $= 0.104 \times 6.02\times10^{23}$ $= 6.25\times10^{22}$	Either method	1 1	2	3.6.2.2
05.3	Volume is constant; change in pressure will be equal to the change in temperature only $\frac{p_2}{p_1} = \frac{T_2}{T_1}$, $T_2 = p_2\frac{T_1}{p_1}$ $= 6.2\times10^{6} \times \frac{723}{3.2\times10^{6}}$ = 1400 K Or $T = \frac{pV}{Nk}$ $= \frac{6.2\times10^{6} \times 195\times10^{-6}}{6.25\times10^{22} \times 1.38\times10^{-23}}$ = 1400 K	Either method	1 1	2	3.6.2.2
05.4	The work done by the gas is bigger because the area is bigger The interna l energy has increased by the combustion of the gas		1 1	3	3.6.2.2
06.1	Change in momentum $= (mv_1) - (-mv_2) = 4.6\times10^{-26} \times (510 - (-510))$ $= 4.69\times10^{-23}$ kg m s^{-1} Time between collisions $= \frac{d}{v} = \frac{0.3}{510} = 5.9\ (5.88)\times10^{-4}$ s	Answer Answer	1 1 1	2	3.4.1.6

A Level AQA Physics

13 Thermal physics – answers

Question	Answers	Extra information	Mark	AO	Spec reference
06.2	Force = rate of change of momentum $= \frac{4.69\times10^{-23}}{5.88\times10^{-4}} = 7.97\times10^{-20}$ N Pressure $= \frac{\text{force}}{\text{area}}$ $= \frac{7.97\times10^{-20}}{0.3\times0.3} = 8.86\times10^{-19}$ Pa	Use of $F = \frac{dmv}{dt}$ Answer	1 1	2	3.4.1.6
06.3	Number of gas molecules $= \frac{100\,000}{8.86\times10^{-19}} = 1.13\times10^{23}$ Number of mols $= \frac{1.13\times10^{23}}{6.02\times10^{23}} = 0.19$ (0.187) mols	Answer	1 1	2	3.6.2.2
06.4	$\frac{3}{2}kT = \frac{1}{3}mc^2$ $T = \frac{2}{9}\frac{m}{k}c^2 = \frac{2}{9}\times\frac{4.6\times10^{-26}}{1.38\times10^{-23}}\times510^2 = 193$ K $pV = nRT$ $T = \frac{pV}{nR} = \frac{100\,000\times(0.3)^3}{0.187\times8.31} = 1737$ K 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 The molecules do not all hit the surface at 90°, so the average change in momentum will be smaller They will collide with other molecules, so the time between collisions will be bigger 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	Two temperatures calculated Reasoning to conclusion that number of mols is larger to include: • angles • force • time	1 1 1 1 1	3	3.6.2.3

A Level AQA Physics
13 Thermal physics – answers

Question	Answers	Extra information	Mark	AO	Spec reference
07.1		Low temperature peaks at lower speed Higher temperature peak lower Correct shape by eye + axes labelled	1 1 1	3	3.6.2.3
07.2	Mean mass of air molecule $= \frac{28.97\times10^{-3}}{6.0\times10^{23}} = 4.8\times10^{-26}$ kg $\frac{1}{2}mv^2 = \frac{3}{2}kT$ $\sqrt{v^2} = \sqrt{\frac{3kT}{m}} = \sqrt{\frac{3\times1.38\times10^{-23}\times(22.6+273.14)}{4.8\times10^{-26}}}$ $= 504\ \mathrm{m\,s^{-1}}$	Calculation of mass Calculation Answer	1 1 1	2	3.6.2.3
07.3	$E_{grav} = -\frac{GMm}{r}$ = energy of a mass m at a distance r from a mass M Assuming that the velocity of an object is zero at infinity $\frac{1}{2}mv^2 + -\frac{GMm}{r} = 0$ $\frac{1}{2}mv^2 = \frac{GMm}{r}$ $v = \sqrt{\frac{2GM}{r}}$	Use of equation for EPE Manipulation	1 1	2	3.7.2.3

A Level AQA Physics
13 Thermal physics – answers

Question	Answers	Extra information	Mark	AO	Spec reference
07.4	Earth: $v_{escape} = \sqrt{\dfrac{2 \times 6.67\times10^{-11}\,N\,m^2\,kg^{-3} \times 5.97\times10^{24}\,kg}{6.378\times10^6\,m}}$ $v_{escape} = 1.12\times10^4\,m\,s^{-1} = 11.2\,km\,s^{-1}$, which is about 22 times the average speed of a molecule of the atmosphere, so the gas molecules are not travelling fast enough to escape The escape velocity of the Moon is only about 5 times greater than the average velocity of a gas molecule at 22.4 °C The temperature of the Moon can be about 4 times greater, which would double the average velocity There would be molecules in the distribution travelling fast enough to escape	Answer Comparison with mean speed Comparison with mean speed Effect of temperature on speed Use of distribution	1 1 1 1 1	3	3.7.2.3
08.1	Energy transferred per second = (mass per second) × $c\Delta T$ = density × volume per second × $c\Delta T$ = 997 × 2.7×10^{-3} × 4200 × (45 – 34) = 1.24×10^5 J s^{-1}	Use of equation for SHC and density answer	1 1	2	3.6.2.1
08.2	$\Delta T = \dfrac{\text{Energy transferred per second}}{\text{density} \times \text{volume per second} \times c}$ $= \dfrac{1.24\times10^5}{1.225 \times 2.2 \times 1000}$ = 46 °C Temperature of the air leaving = 16 + 46 = 62 °C Assuming all the energy transferred from the water is transferred to the air	Calculation to find temperature difference Answer Assumption	1 1 1	2	3.6.2.1
08.3	Energy is transferred to the material of the pipe/casing of the heater/the air is not heated completely because of convection		1	1	3.6.2
08.4	A current flows in a coil inside the motor, which is in a magnetic field There is a force on each side of the coil causing it to spin		2	1	3.7.5.1

13 Thermal physics – answers

Question	Answers	Extra information	Mark	AO	Spec reference
08.5	The coil is a conductor in a magnetic field, so an e.m.f. is induced in it when it spins The direction of the e.m.f. is in a direction so as to oppose the motion that caused it, so produces an e.m.f. that reduces the current (Lenz's law)		1 1	3	3.7.5.4

Skills box answers

Question	Answer
1	The pressure should be increased slowly, and the apparatus allowed to cool between measurements.
2	A straight-line graph that passes through the origin (p proportional to $\frac{1}{V}$; axes labelled.
3