IGC HK EXAM - WJEC

WJEC & Eduqas - Physics

Mock 1 Practice Paper

2017

3. *(a)* The magnitude of the acceleration of a body travelling at speed v in a circle of radius r is given by:

$$a = \frac{v^2}{r}$$

(i) Show clearly that this equation is homogeneous in terms of units. [2]

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(ii) A teacher claims that the equation gives a 'sensible' value for the centripetal acceleration as r becomes extremely large. Justify her claim. [2]

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(b) A car of mass 1 150 kg moving at constant speed takes 52 s to complete a lap of a flat circular track of radius 200 m.

(i) Show that the magnitude of the centripetal force on the car is approximately 3400 N. [3]

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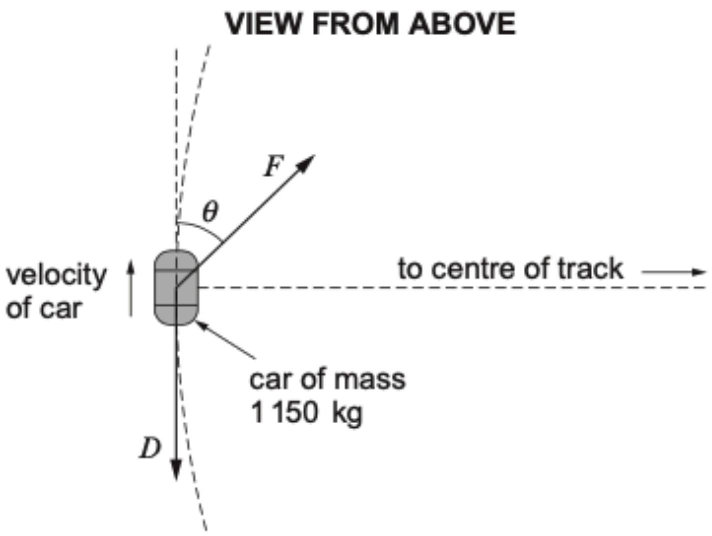
(ii) The diagram shows the car at one point on its journey (clockwise) around the track. D is the force of air resistance on the car, and F is the horizontal component of the force on the car's tyres from the road. F = 5 500 N.



I. Calculate the angle, θ, at which F must act in order to provide the centripetal force calculated in *(b)*(i). [2]

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II. Calculate D, giving your reasoning. [3]

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Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
3	*(a)*	(i)		Units of a, v, r given as m s^{-2}, m s^{-1}, m (1) Convincing algebra **must see** m^2 s^{-2} (1)	1	1		2	1	
		(ii)		[According to equation] a becomes smaller **or** zero (1) [Sensible because] body's path [almost] straight **or** equivalent (1)			2	2		
	(b)	(i)		$v = \frac{2\pi \times 200}{52}$ [= 24.2 m s^{-1}] or ω = 0.121 [rad s^{-1}](1) F_{centrip} = 1 150 × ($\frac{2\pi \times 200}{52}$)^2 ÷ 200 [N] or equivalent or by implic(1) F_{centrip} = 3 360 [N] **or** 3 400 [N] **Accept** 3 358 [N] or 3 300 [N] (1)		3		3	3	
		(ii)	I	$F_{\text{centrip}} = F \sin\theta$ **or** 3 360 (or 3 000) = 5 500 $\sin\theta$ **or** equiv **or** by implic **ecf** on F_{centrip} (1) θ = 37.6°(or 38°) (1)		2		2	2	
			II	Forward component of F must balance D (**or** must be equal and opposite to D) **or** since car is travelling at constant speed (1) $D = F\cos\theta$ or equiv **ecf on θ**(1) D = 4 360 [N] (1)	1	1 1		3	2	
				Question 3 total	**2**	**8**	**2**	**12**	**8**	**0**

2018

2. *(a)* (i) Define the angular velocity, ω, for a body moving in a circle. [1]

(ii) Two equations giving the acceleration of a body moving at constant speed in a circle are:

$$a = \frac{v^2}{r} \quad \text{and} \quad a = r\omega^2.$$

Show clearly that the equations are equivalent. [2]

(b) A moon called *Deimos* orbits Mars in a circular path of radius 23 500 km. Astronomers have calculated the mass of Deimos to be 1.48×10^{15} kg, and the force exerted on it by Mars to be 1.15×10^{14} N.

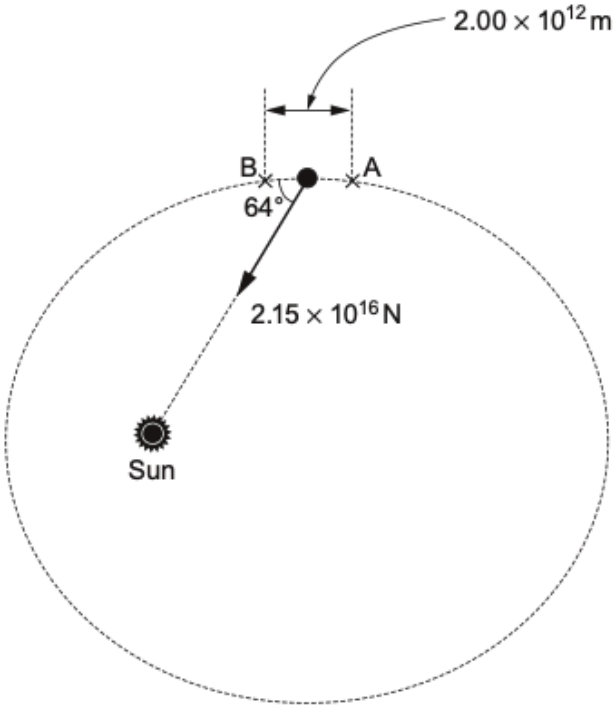
(i) Calculate the speed of Deimos around Mars. [2]

(ii) Explain whether or not a moon of twice the mass of Deimos, but in a circular orbit of the same radius about Mars, would have the same speed as Deimos. [2]

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
2	*(a)*	(i)	$\omega = \frac{\text{angle swept out}}{\text{time taken}}$ [or in words] **Or** angle [accept: number of radians] swept out per unit time [or per second]	1			1		
		(ii)	Clear use of $\omega = \frac{v}{r}$ or equivalent (1) Convincing algebra (1)	1	1		2	1	
	(b)	(i)	Substitution into: $F = m\frac{v^2}{r}$ or equivalent either before or after rearrangement (1) v = 1.35 km s^{-1} (1)	1	1		2	1	
		(ii)	$\frac{GMm}{r^2} = \frac{mv^2}{r}$ or equivalent with M and m correctly identified (1) m cancels so speed of moon of twice the mass would be the same as that of Deimos. [Must be supported by argument even if argument not clear enough to give first mark.] (1) **or** in words, e.g. Equivalence of gravitational and inertial mass however expressed, [e.g. the force would be double and the mass is doubled] (1) Hence speed the same (1) **or** Another identical moon next to the existing one will orbit at the same speed (1), so the composite moon [of double the mass] will orbit at that speed (1).		2		2		
			Question 2 total	**3**	**4**	**0**	**7**	**2**	**0**

2019

2. The diagram shows the dwarf planet, Eris, at one point in its orbit.



(a) Explain why the *moment* (about the centre of the Sun) of the Sun's force on Eris is zero. [1]

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(b) Calculate the *work* done by the Sun's gravitational force on Eris as Eris moves from A to B. The mean values of the force and the angle at which it acts are shown on the diagram. [2]

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(c) Showing your reasoning clearly, determine whether your answer to *(b)* is consistent with these data:

$$\text{Mass of Eris} = 1.66 \times 10^{22}\,\text{kg}$$

$$\text{Speed of Eris at A} = 3460\,\text{m s}^{-1}$$

$$\text{Speed of Eris at B} = 3770\,\text{m s}^{-1}$$

[3]

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Question		Marking details	Marks available					
			AO1	**AO2**	**AO3**	**Total**	**Maths**	**Prac**
2	*(a)*	Zero distance from Sun to line of action of force **accept** zero perpendicular distance **or** [line of action of] force is straight through [centre of] Sun		1		1		
	(b)	Work $= 2.15 \times 10^{16} \times 2.0 \times 10^{12} \times \cos 64°$ [1] $= 1.88 \times 10^{28}$ J **unit mark** [1]	1	1		2	2	
	(c)	Work = ΔE_k declared as strategy **or** implied by conclusion **ecf** from (b) provided comment made [1] Intermediate step: $E_{kA} = 9.94 \times 10^{28}$ [J] **or** $E_{kB} = 1.18 \times 10^{29}$ [J] **or** $v_B^2 - v_A^2 = 2.24 \times 10^6$ [$\text{m}^2\,\text{s}^{-2}$] or correct substitution into $\frac{1}{2}mv_B^2 - \frac{1}{2}mv_A^2$ [1] $E_{kB} - E_{kA} = 1.86 \times 10^{28}$ [J] **clearly arrived at** [1]			3	3	2	
		Question 2 total	**1**	**2**	**3**	**6**	**4**	**0**

4. *(a)* A fairground ride rotates at a rate of 8.20 revolutions per **minute**.

(i) Calculate:

I. the angular velocity in radians per second; [2]

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II. the time taken to travel an arc of length 10.0 m for a point P on the ride at 3.80 m from the central axis around which the ride is rotating; [2]

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III. the acceleration of point P. [2]

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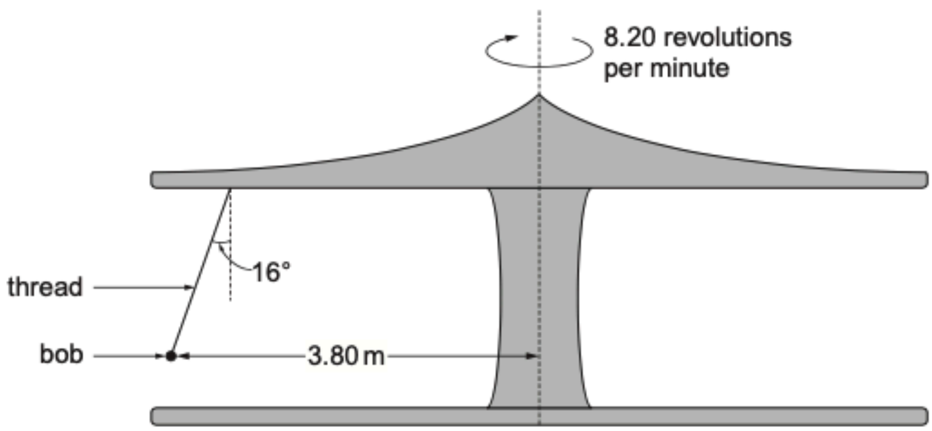
(ii) Annushka has been given permission to tie a simple pendulum from the ceiling of the rotating ride. She finds that, when the pendulum has stabilised, it hangs at 16° to the vertical, with its bob at 3.80 m from the central axis (see diagram).



I. The mass of the bob is 0.270 kg. By considering the **vertical** force components on the bob, calculate the tension in the thread. [2]

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II. State what provides the centripetal force on the bob and show clearly whether or not this is consistent with the acceleration calculated in *(a)*(i)III. [3]

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(b) Discuss **one** way in which our knowledge of the magnitude of centripetal force has been applied in the design of roads **or** railways **or** a domestic appliance. [3]

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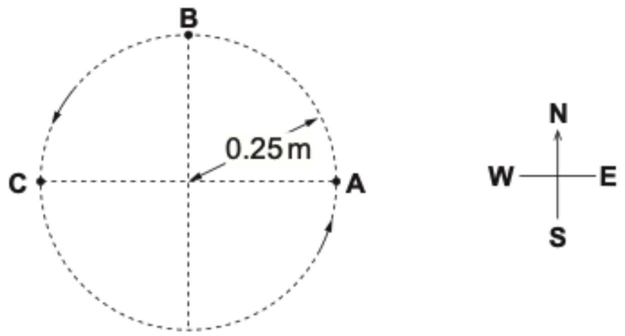
Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
4	*(a)*	(i)	I	Use of $\omega = 2\pi f$ even if f is still in revs per minute **or by impl** [1] ω = 0.859 [rad s^{-1}] [1]	1	1		2	1	
			II	Use of $v = r\omega$ [= 3.26 m s^{-1}] **or equiv or by impl.** [1] Time = 3.06 [s] [1] **ecf**	1	1		2	1	
			III	Use of $a = \frac{v^2}{r}$ or $a = r\omega^2$ **or by implication** [1] a = 2.80 [m s^{-2}] [1] **ecf**	1	1		2	1	
		(ii)	I	Correct substitutions in $mg = T\cos\theta$ (or after transposition) or by implication [1] 2.76 [N] [1] [2.55 N indicates error of principle]		2		2	1	
			II	[Horizontal component of] tension provides centripetal force [1] $T\sin 16°$ evaluated [0.761 N **ecf on** T] or used in calculation [1] Conclusion clearly based on calculation e.g. Either $\frac{2.76 \sin 16°}{0.270}$ = 2.82 [m s^{-2}] **or** 2.80 **ecf** from (a)(i)III × 0.270 kg = 0.756 [N] **and** agreement noted **ecf** [1]			3	3	2	
	(b)			Example defined e.g. bends in roads or rail lines, spin-drier... [1] One factor affecting centripetal acceleration considered in context e.g. bends in roads or tracks must not be too sharp, or spin speed must be high enough... [1] Another factor considered e.g. vehicle speed warnings, drum size limited **or** more intricate measures e.g. banking of tracks [1]			3	3		
				Question 4 total	**3**	**5**	**6**	**14**	**6**	**0**

2020

2. *(a)* State what is meant by a body's *mean acceleration* over a period of time. [1]

(b) Protons are 'stored' by being made to go round and round a circular path of radius 0.25 m at constant speed. They perform 5.2×10^6 revolutions per second.



(i) Show clearly that the protons' speed is approximately $8 \times 10^6\,\mathrm{m\,s^{-1}}$. [2]

(ii) Determine the magnitude and direction of a proton's acceleration at point **B**. [3]

(iii) Calculate a proton's mean acceleration over the semicircle **ABC**. [3]

(c) Two students discuss the mean force on a proton over one revolution **ABCA**. Adam says that the mean force is the same as the force at B, because the force is the same all the way round. Brian says that the mean force is zero. Evaluate these opinions. [2]

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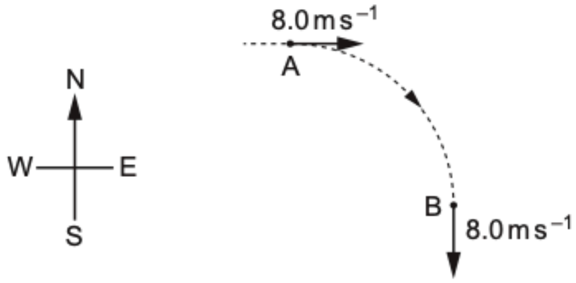
Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
2	(a)			$\frac{\text{final velocity - initial velocity}}{\text{time [taken to change]}}$ or equivalent [1]	1			1		
	(b)	(i)		[Distance gone per second] = $2\pi \times 0.25$ [m] $\times$ 5.2×10^6 [s^{-1}] [1] = 8.2×10^6 [m s^{-1}] [1]	1	1		2	2	
		(ii)		acc = $\frac{(8.0\times10^6)^2}{0.25}$ [m s^{-2}] **or** $\frac{(8.17\times10^6)^2}{0.25}$ [m s^{-2}] [1] = 2.6 (or 2.7) $\times$ 10^{14} m s^{-2} **unit mark** [1] South or towards circle centre. Accept downwards. [1]	1 1	1		3	1	
		(iii)		Time for half revolution = $\frac{1}{2} \times \frac{1}{5.2\times10^6}$ s [= 9.62×10^{-8} s] [1] Final velocity – initial velocity = 1.63×10^7 [m s^{-1}] [South] [1] Mean acc = 1.7×10^{14} [m s^{-2}] **South** [Accept South for Δv] [1]		3		3	2	
	(c)			Adam is wrong because acc's (or force) *direction* keeps changing [1] Brian is right because final vel – initial vel = 0 or equiv [1]			2	2		
				Question 2 total	**4**	**5**	**2**	**11**	**5**	**0**

20210

4. *(a)* A car travels around a bend in a road at a constant speed of $8.0\,\text{m}\,\text{s}^{-1}$. It takes 2.5 s to go from A to B. The diagram shows the car's velocities at A and B.



Determine the magnitude and **compass direction** of the car's **mean** acceleration as it goes from A to B. [3]

(b) In special circumstances an electron has been made to orbit a nucleus in a circular orbit of radius 0.37 mm.

(i) Comment on the radius of this atomic orbit. [1]

(ii) Assuming the charge on the nucleus to be $+e$, show that the speed of the electron is approximately $800\,\text{m}\,\text{s}^{-1}$. [3]

(iii) Calculate the frequency at which the electron orbits. [2]

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Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
4	*(a)*			$\Delta v = 8.0\sqrt{2}\,[\mathrm{m\,s^{-1}}]\ [= 11.3\ \mathrm{m\,s^{-1}}]$ or by implic [1] a = 4.5 [m s^{-2}] [1] South West **or** bearing of 225° [1]		3		3	2	
	(b)	(i)		Very large [for an atom]. Accept definite orbit not possible	1			1		
		(ii)		$\frac{m_e v^2}{r} = \frac{1}{4\pi\varepsilon_0}\frac{e^2}{r^2}$ or by implic [1] $v = \sqrt{\frac{1}{4\pi\varepsilon_0}\frac{e^2}{m_e r}}$ **or** $v = \sqrt{9.0\times10^9\ \frac{(1.60\times10^{-19})^2}{9.11\times10^{-31}\times0.37\times10^{-3}}}\ \mathrm{m\,s^{-1}}$ or by implic [1] v = 827 [m s^{-1}] [1]		3		3	2	
		(iii)		$f = \frac{827}{2\pi\times0.37\times10^{-3}}$ [Hz] or equiv or by implic [1] f = 3.6 [or 3.4] × 10^5 Hz [**or** s^{-1}] **unit mark** [1]	1	1		2	1	
				Question 4 total	**2**	**7**	**0**	**9**	**5**	**0**

2022

4. (a) Explain why an object moving in a circular path requires a resultant force to act on it, even when it is travelling at constant speed. [2]

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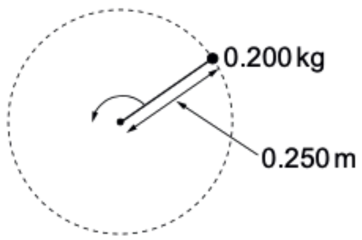
(b) Behind a safety screen in an engineering laboratory, a metal sphere of mass 0.200 kg is whirled in a horizontal circle on the end of a thin steel rod.



View from above

(i) The breaking stress of the steel under tension is 450 MPa and the **rod's diameter** is 1.2 mm. Show that the greatest force that the rod can exert is roughly 500 N. [2]

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(ii) Calculate the greatest rotation frequency (number of revolutions per second) at which the sphere can be whirled before the rod breaks. [3]

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(iii) I. State an assumption that you have made (or factor that you have ignored) in your calculation for part (b)(ii). [1]

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II. Bearing in mind your previous answer, will the greatest rotation frequency before the rod breaks be larger or smaller than your calculated value? Justify your answer briefly. [1]

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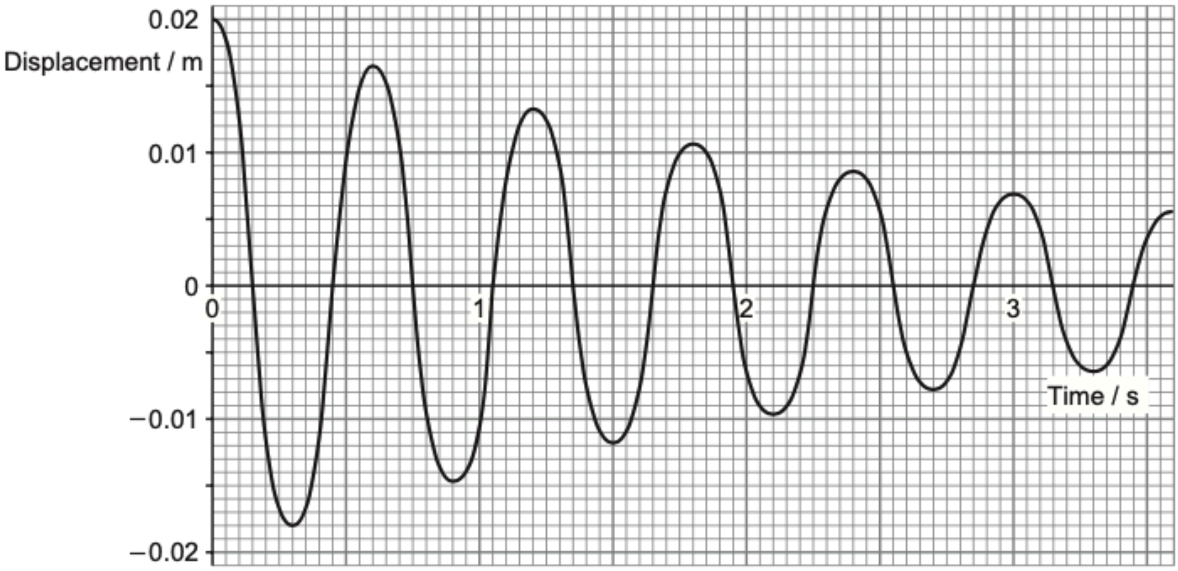
Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
4	(a)			Object is accelerating [or velocity changing] because direction [of travel] [continuously] changing (1) [Resultant] force needed to give object an acceleration **or** a velocity change [or $F = ma$ cited] (1)	2			2		
	(b)	(i)		Force = 450 × 10^6 × π × 0.0006^2 [N] (1) [Tolerate slips in powers of 10 or factors of 2 or 4 for this mark only] = 509 N or 510 N [N] (1)	1	1		2	1	
		(ii)		Insertion of values for F, m, and r into $F = \frac{mv^2}{r}$ or $F = mr\omega^2$ or by implication (1) $v = \sqrt{\frac{509 \times 0.250}{0.200}}$ [= 25.2 m s^{-1}] **or** $\omega = \sqrt{\frac{509}{0.200 \times 0.250}}$ [$= 101 \text{ rad s}^{-1}$] or by implication (1) f = 16 [Hz] **ecf** on v or ω (1)	1 1	1		3	2	
		(iii)	I	Mass of rod ignored **or** stretching of rod ignored [or any other significant assumption or factor ignored]		1		1		
			II	Mass of rod makes greatest rotation rate smaller **or** more stress on [inner part] of rod [for a given rotation rate] **or** stretching makes greatest rotation rate smaller **or** more stress for a given rotation rate.			1	1		
				Question 4 total	**5**	**3**	**1**	**9**	**3**	**0**

2017

4. A metal sphere of mass 0.200 kg, hanging from a light spring of stiffness k = 22.0 N m^{-1}, is set oscillating up and down about its equilibrium position. A datalogger records the sphere's position and plots the graph shown below.



(a) State what feature of the graph shows that the sphere's oscillations are damped and identify the force responsible for this feature. [2]

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(b) Evaluate whether or not ordinary simple harmonic motion theory predicts the actual periodic time as shown on the graph convincingly. [4]

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(c) **Mark with a small circle** the point on the graph where the sphere's speed is the greatest. Use shm theory to calculate a value for this speed **and** explain whether this value is likely to be too high or too low. [4]

(d) The amplitude, A, (in m) of the oscillations at time t is given by the equation:

$$A = 0.020\, e^{-\lambda t}$$

Determine the value of λ. [2]

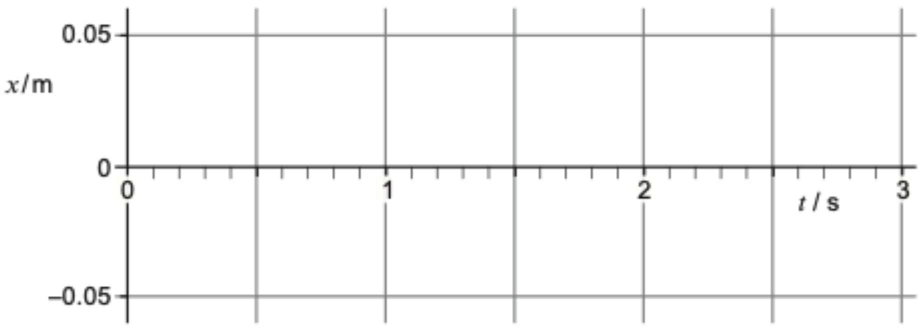
Question			Marking details	Marks available				Maths	Prac
				AO1	AO2	AO3	Total		
4	*(a)*		Falling amplitude (1) [Air] resistance **or** dissipative forces **or** equivalent (1)	2			2		
	(b)		$T = 2\pi\sqrt{\frac{0.200}{22.0}}$ [s] (1) = 0.599 [s] (1) T read from graph = 0.60 [s] (1) Prediction convincing [no significant difference] (1)			4	4	2	
	(c)		Point at 0.15 s marked – no tolerance (first displacement zero) (1) $v_{\text{max}} = 0.020 \times \frac{2\pi}{0.60}\left[\text{m s}^{-1}\right]$ (1) = 0.21 m s^{-1} **UNIT** (1) Too large owing to energy dissipation in first quarter cycle (1) **Accept** less detailed reason, such as 'because of damping' **Alternative for last 3 marks:** $v_{\text{max}} = 0.018 \times \frac{2\pi}{0.60}\left[\text{m s}^{-1}\right]$ (1) = 0.19 m s^{-1} **UNIT** (1) Too small because amplitude has fallen or equivalent (1) **Alternative for last 3 marks (mean found):** $v_{\text{max}} = 0.019 \times \frac{2\pi}{0.60}\left[\text{m s}^{-1}\right]$ (2) = 0.20 m s^{-1} **UNIT** (1) no comment required	1	1 1 1		4	2	
	(d)		Data from one maximum or minimum on the graph (other than at t = 0) substituted into the given equation or equivalent accept slips (1) $\lambda = 0.35\ [\text{s}^{-1}]\ [\pm 0.03\ \text{s}^{-1}]$ (1)		2		2	1	
			Question 4 total	**3**	**5**	**4**	**12**	**5**	**0**

2018

5. *(a)* Rachel investigates a simple pendulum consisting of a small metal sphere suspended by a thread. She determines its period to be 2.40 s.

(i) Calculate the length of the pendulum. [2]

(ii) Rachel now displaces the sphere by 0.050 m to one side of its equilibrium position and releases it at time t = 0.



I. Sketch a graph of displacement, x, against time, t, for the sphere between t = 0 and t = 3.00 s **on the grid provided**. Take the initial value of x to be positive. [2]

II. Use an appropriate equation to calculate the sphere's displacement at t = 1.60 s. [2]

III. Calculate the sphere's velocity at t = 1.60 s. [2]

IV. State the next time at which the sphere has the same velocity. [1]

(b) Explain what is meant by *resonance*, and how its effects can be reduced in a particular case where resonance should be avoided. [6 QER]

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
5	*(a)*	(i)		Correct substitution of data (1) $\ell = 1.43$ m (1)	1	1		2	2	2
		(ii)	I	Recognisable cosine graph of amplitude 0.050 m (1) Zeros at approximately 0.6 s, 1.8 s, 3.0 s, that is correct period [even if –cosine graph] (1)		2		2	1	2
			II	x [/m] $= 0.050 \cos 2\pi \frac{1.6}{2.4}$ or equivalent or by implication (1) $x = -0.025$ m (1) If no working given, 0 marks for any incorrect answer (e.g. –0.24 m)		2		2	2	2
			III	v [/m s^{-1}] $= -0.050 \times \frac{2\pi}{2.4} \sin 2\pi \frac{1.6}{2.4}$ or equivalent (1) $v = 0.11$ m s^{-1} (1) For tangent method on sketch graph, award the second mark for 0.11 ± 0.03 m s^{-1}		2		2	2	2
			IV	2.0 s		1		1		1

Question				Marking details	Marks available				Maths	Prac
					AO1	AO2	AO3	Total		
	(b)			**A: Meaning of resonance** A1 Term applies to forced oscillations. A2 Forced oscillations occur when a system is subjected to a periodic driving force. A3 Resonance occurs at a particular frequency of driving force… A4 .. which is the same frequency as the system's natural frequency A5 At resonance the amplitude of the oscillations is a maximum [for a given amplitude of driving force]. **B: How effects can be lessened** B1 System mentioned where resonance is a nuisance (e.g suspension bridge). B2 A little information given about the oscillations and/or the driving force for this system. B3 Increasing the damping will lessen the amplitude of the oscillations. B4 Making sure the forcing frequency avoids the system's natural frequency (e.g. by shifting system's natural frequency) will also lessen amplitude	6			6		

2019

5. *(a)* Define *simple harmonic motion*. [2]

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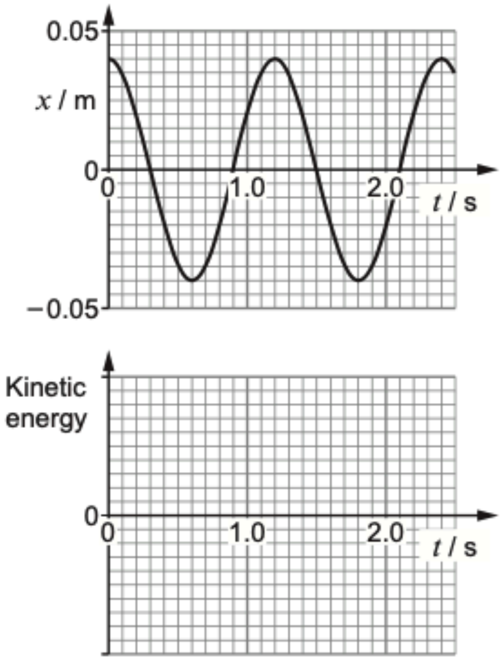
(b) A metal sphere of mass 0.175 kg hangs from a spring whose top end is clamped. The sphere is set oscillating up and down, and a displacement-time graph is plotted.



GRID FOR *(b)*(iii)

(i) Calculate the stiffness constant, k, of the spring. [3]

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(ii) Calculate the maximum kinetic energy of the sphere. [3]

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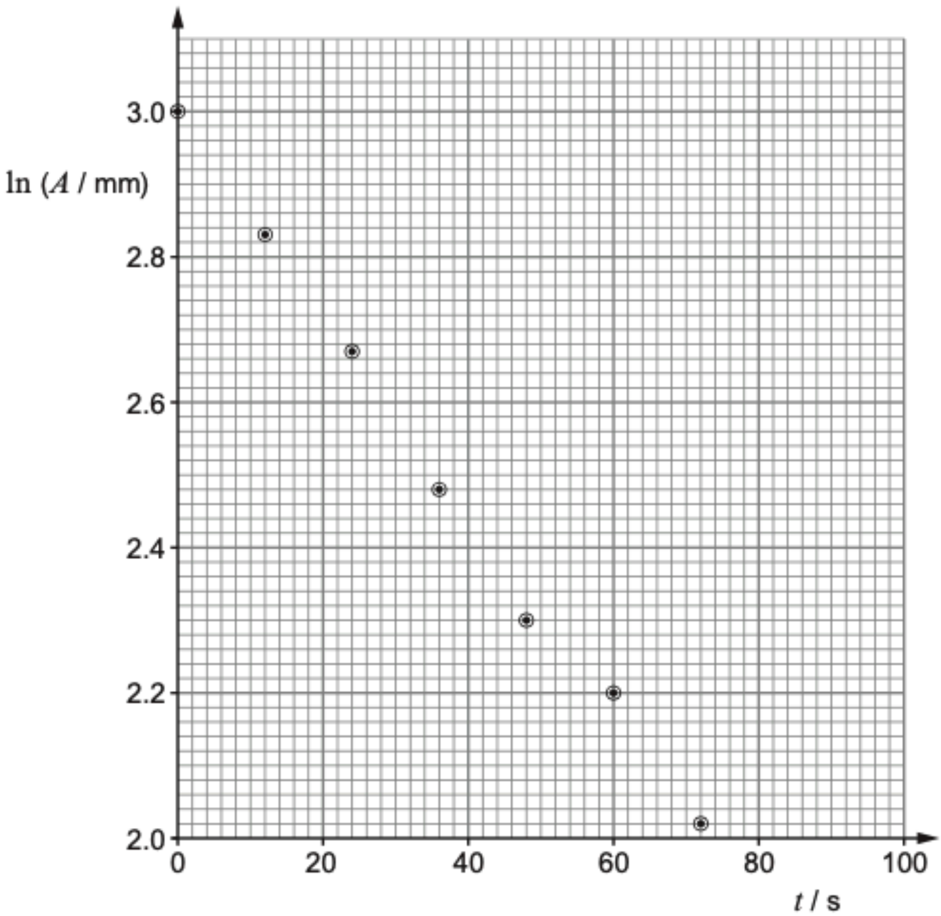
(iii) Carefully sketch a graph of the sphere's kinetic energy against time **on the axes provided on the opposite page**. A vertical scale is **not** needed. [3]

(c) Over several oscillations it is clear that the amplitude of the sphere's motion is decreasing. Evgeniya suspects that the amplitude is decreasing exponentially, according to the equation:

$$A = A_0 e^{-\lambda t}$$

To check this idea she uses readings of the amplitude, A, taken at regular intervals to plot $\ln (A / \text{mm})$ against time, t.



Evgeniya claims that the points she has plotted support the exponential decrease of amplitude. Justify her claim **and** determine a value for λ. [5]

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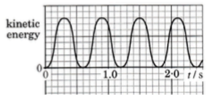
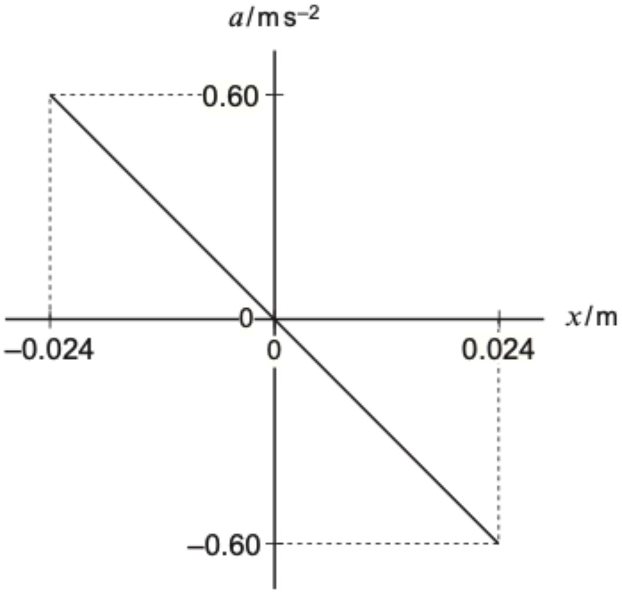
Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
5	*(a)*			[Motion such that] acceleration proportional to displacement from a fixed point [1] but in opposite direction **or** directed towards that point [1] **or** $a = -\omega^2 x$ with a = acceleration and x = displacement [1] ω [or ω^2] constant [1]	2			2		
	(b)	(i)		T = 1.2[0] s (from graph) or by implication [1] Correct re-arrangement $k = \frac{4\pi^2 m}{T^2}$ at any stage **or by impl.** [1] k = 4.80 N m^{-1} **unit mark** [1]		3		3	2	
		(ii)		Correct use of $v_{max} = A\omega$ [= 0.209 m s^{-1}] **or by implic** [1] Correct use of $E_k = \frac{1}{2}mv^2$ **ecf** on slips in v_{max} [1] $E_{k\,max}$ = 3.8 × 10^{-3} J [1]	1 1	1		3	2	
		(iii)		 Zeros at t = 0, 0.6 s, 1.2 s, 1.8 s, 2.4 s [1] KE never negative with equal peaks [1] Smooth (sinusoidal) curve [1]	1 1	1		3	2	
	(c)			Reasonable straight line of best fit drawn [1] Straight line expected as equation equivalent to $\ln A = \ln A_0 - \lambda t$ [1] Some comment about scatter of points – either supporting or casting doubt on straight line [1] λ = –gradient **or by impl.** [1] Gradient calculated correctly e.g. 0.014 [s^{-1}] No *second* penalty for mishandling minus sign [1]			5	5	3	5
				Question 5 total	**6**	**5**	**5**	**16**	**9**	**5**

2020

3. *(a)* The acceleration, a, of a body is plotted against its displacement, x, from a fixed point.



(i) State the features of the **graph** that show the body is performing *simple harmonic motion.* [2]

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(ii) Determine the *amplitude* of the motion. [1]

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(iii) Calculate the *periodic time* of the motion. [3]

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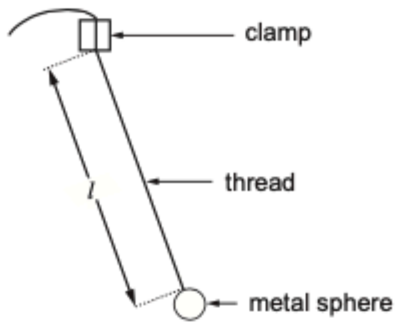
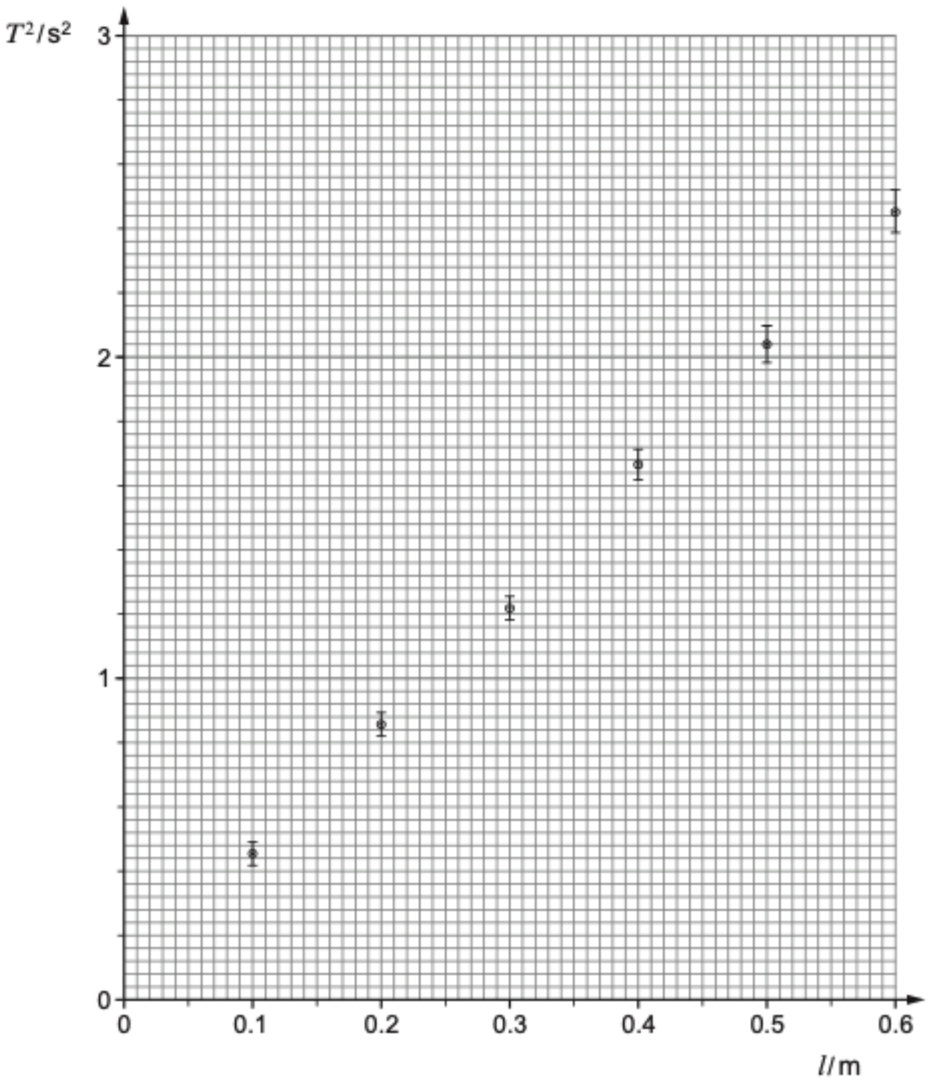
(b) Charlotte performed an experiment to determine the acceleration due to gravity, g, using a simple pendulum.



Using a metre ruler she measured the length, l, shown in the diagram. She then recorded the time for 10 small amplitude oscillations, repeated the timing and calculated values for the mean periodic time, T, and its uncertainty. She repeated the procedure for another five values of l. She plotted her values of T^2 against l on the following grid.



(i) State why you would not expect the line of best fit to pass exactly through the origin. [1]

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(ii) Determine a value for the acceleration due to gravity, g, together with its **percentage** uncertainty. Give your reasoning clearly. [6]

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(c) A tennis ball attached by a **spring** to a fixed point is displaced vertically from its equilibrium position and released. It performs *damped oscillations.*

(i) What observed feature of the oscillations shows them to be damped? [1]

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(ii) Explain in terms of *forces* how the damping comes about. [2]

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(d) Explain what is meant by *critical damping*, **and** state one application of critical damping (or of damping that is close to critical). [3]

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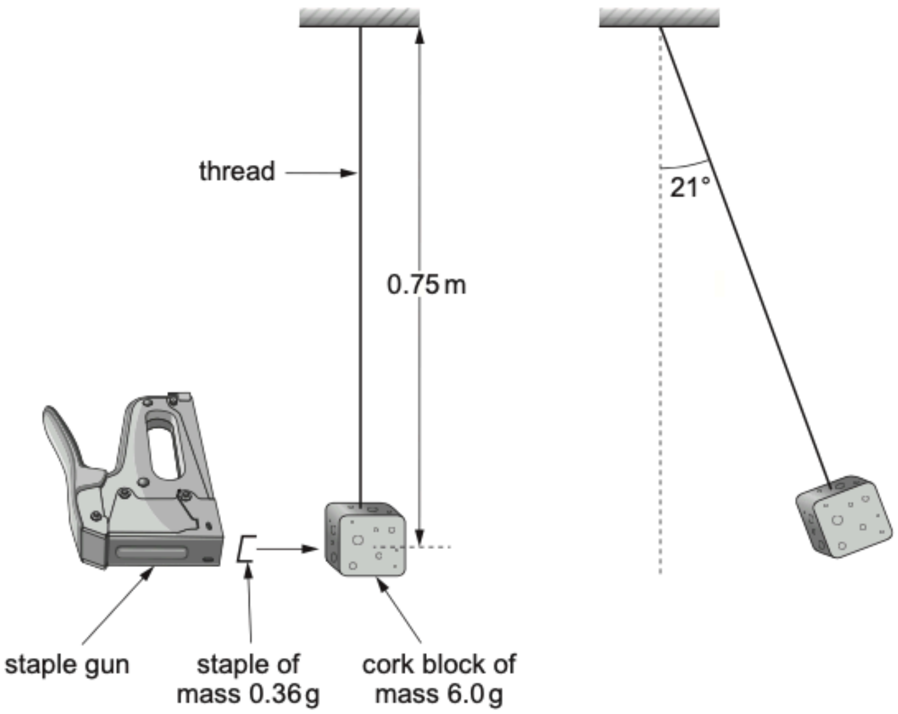
Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
3	(a)	(i)		Straight line through origin [1] Negative gradient [1] [1 mark for a whole answer like "Acceleration proportional to negative displacement" i.e. without referring to graph]	2			2		
		(ii)		0.024 [m]	1			1		
		(iii)		$\omega^2 = \frac{0.60}{0.024}$ [$= 25\ \text{s}^{-2}$] [1] $T = \frac{2\pi}{5\ [s^{-1}]}$ ecf on ω^2 [1] *T* = 1.26 [s] **no ecf** [1]		3		3	3	
	(b)	(i)		No. l not measured to centre of sphere.			1	1		1
		(ii)		Graph gradient = $\frac{4\pi^2}{g}$ or equivalent [1] Correct division sum set up to calculate gradient from graph [1] Max gradient between 4.0 and 4.2 [$\text{s}^2\ \text{m}^{-1}$] [1] Min gradient between 3.7 and 3.9 [$\text{s}^2\ \text{m}^{-1}$] [1] $g = 9.9\ \text{m s}^{-2}$ **ecf** on mean gradient [1] Uncertainty 5 % **ecf** on max and min gradients [1]			6	6	4	6
	(c)	(i)		Decreasing amplitude (or equivalent)	1			1		
		(ii)		Resistive or dissipative forces (or equivalent incl air res) [1] [Always] oppose motion **or** transfer energy from system/ball [1]	2			2		

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
	(d)			Body, displaced and released, returns to equilibrium without oscillating **or** without overshoot [1] Resistive force just large enough for this (or equiv) [1] Car suspensions (or other plausible example) Accept bridges [1]	3			3		
				Question 3 total	**9**	**3**	**7**	**19**	**7**	**7**

2021

3. Charlotte uses the apparatus shown to determine the speed at which a staple leaves a staple gun.



The cork block is set moving to the right by the collision, coming to rest momentarily when the thread is at an angle of 21° to the vertical.

(a) (i) State the *principle of conservation of energy.* [1]

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(ii) Show that the block's speed just after the staple has **embedded itself** is approximately 1 m s^{-1}. [4]

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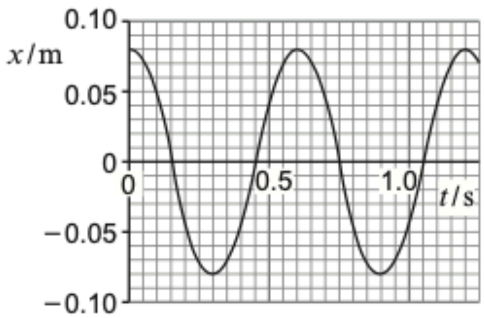
(b) Determine the speed of the staple just before it entered the block. [2]

(c) Charlotte claims that the block would have swung higher if the staple had bounced back off the block instead of embedding itself. Evaluate this claim. [2]

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
3	*(a)*	(i)		Energy cannot be created or destroyed but can be transferred from one form to another	1			1		
		(ii)		Δh = 0.75 [m] – 0.75 [m] × cos 21° or by implic [1] Δh = 0.050 [m] or by implic [1] $\frac{1}{2}[m]v^2 = [m]gh$ or equiv or by implic [1] v =0.99 [m s^{-1}] **ecf** on Δh [1] **or:** Angle small enough for SHM [approx.] [1] $A = 0.75\text{ m} \times$ sin 21° [1] or 0.269 m by implic $\omega = \sqrt{\frac{g}{l}}$ [1] or $\sqrt{\frac{9.81\text{ [m s}^{-2}]}{0.75\text{ [m]}}}$ or 3.62 [rad s^{-1}] $\boldsymbol{v} = 17.5\text{ [m s}^{-1}]$[1]	1	1 1 1		4	3	
	(b)			0.36 v = 6.36 × 0.99 [1] or by implic v = 17.5 [m s^{-1}] [1] [1 mark for using 6.00 instead of 6.36, leading to 16.5 m s^{-1}] or for incorrect addition of masses]	1	1		2	1	
	(c)			Staple's change of momentum is greater [1] So more momentum given to block, which rises higher, so Charlotte is right [1] **or**: For a given (or greater) momentum given to it [1] the lighter block (without staple) will move off faster, so Charlotte is right [1]			2	2		
				Question 3 total	**3**	**4**	**2**	**9**	**4**	**0**

5. *(a)* A light spring hangs from a fixed support. A mass of 0.200 kg is fastened to its lower end, displaced **upwards** from its equilibrium position, and released at time $t = 0$.

A data-logger is used to produce a graph of displacement, x (from the equilibrium position) against time, t.



(i) Sally measured the **equilibrium extension** of the spring, when loaded with the 0.200 kg mass, recording it as 90 mm. Evaluate whether or not this is consistent with the period of the oscillations. [4]

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(ii) I. **Mark a point**, **P**, on the graph at which the acceleration is upwards and has its greatest value. [1]

II. Calculate this acceleration. [2]

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(iii) I. Calculate the kinetic energy of the mass at t = 0.10 s. [3]

II. Between t = 0 and t = 0.15 s, the mass gains kinetic energy and loses gravitational potential energy. Without further calculation, explain why the gain in kinetic energy is considerably less than the loss of gravitational potential energy. [2]

(b) The mass-spring system of part *(a)* is made to perform forced oscillations.

(i) State the difference between forced oscillations and natural oscillations. [2]

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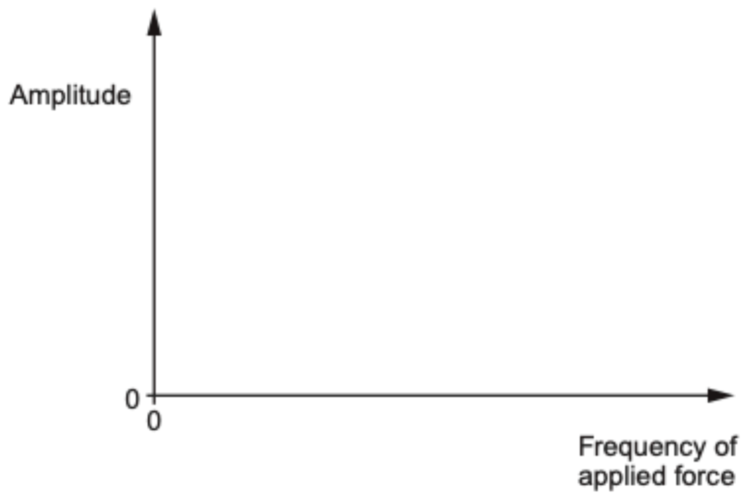
(ii) **Sketch a *resonance curve*** for these forced oscillations on the axes provided. Scales are not required. **Label the numerical value** of the resonance frequency at the appropriate place on the frequency axis. [3]



(c) Sally says "Damping should always be avoided because it involves energy dissipation". Evaluate this claim. [3]

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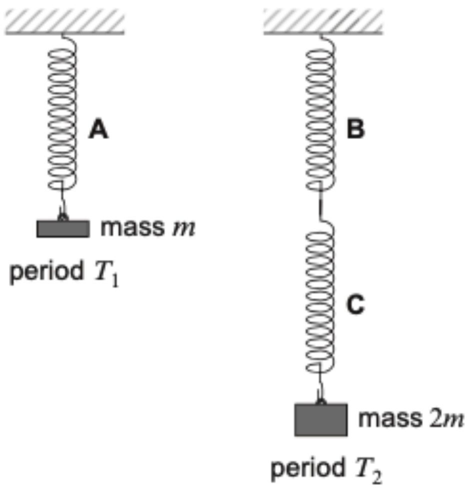
Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
5	*(a)*	(i)		**Either** $k = \frac{0.200 \times 9.81}{0.090}$ [N m^{-1}] [1] [= 21.8 N m^{-1}] or by implic giving $T = 2\pi\sqrt{\frac{0.200}{21.8}}$ [s] **ecf** [1] or by implic giving T = 0.60(2) [s] [1] From graph T = 0.60 [s] with comment e.g. 'very close' [1] **Or:** From graph T = 0.60 [s] [1] $k = \frac{4\pi^2 m}{T^2}$ [1] transposed at any stage, or by implic giving $k = \frac{4\pi^2 \times 0.200}{0.60^2}$ [N m^{-1}] [1] [= 21.9 N m^{-1}] or by implic giving eq ext $\left[= \frac{0.200 \times 9.81}{21.9}\text{ m}\right]$ = 0.90 [m] with comment [1] [**or** k values obtained both from T and from 90 mm + comment]			4	4	3	
		(ii)	I	Either of the two lowest points marked		1		1	1	
			II	$a = \frac{21.8 \text{ or } 21.9}{0.200} \times 0.080$ **or** $\left(\frac{2\pi}{0.60}\right)^2 \times 0.080$ or by implic [1] a = 8.7 m s^{-2} [or 8.8] [m s^{-2}] full **ecf on** k or T [1]	1	1		2	1	
		(iii)	I	$v = -0.080 \times \frac{2\pi}{0.60} \times \sin\left(\frac{2\pi}{0.60} \times 0.10\right)$ [m s^{-1}] or equv or by impl[1] v = [–] 0.726 [m s^{-1}] or by implic [1] $E_k = \left[\frac{1}{2} \times 0.20 \times 0.726^2 \text{ J} =\right]$ 0.053 [J] [1] **ecf on v**		3		3	2	
			II	Elastic PE gained as well as KE [1] Because spring extension increases **or** KE = grav PE [lost] – Elastic PE [gained] [1]		2		2		

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
	(b)	(i)		Forced: system acted on by periodic [driving] force [1] Natural: system disturbed and released [1]	2			2		
		(ii)		Correct curve, with non-zero amplitude at f = 0 [1] Resonance frequency of 1.6 Hz or 1.7 Hz [1] Marked on axis under peak [1]	1 1	1		3		
	(c)			3 out of 4 of the following [3] • Energy dissipation implies a temperature rise that might be hazardous **or** wastes energy. Accept reduces efficiency or damps desired oscillations • But amounts of energy involved usually too small to matter • A maximum of two examples when damping is useful, e.g. in car suspensions, suspension bridges, soft-closure systems [Accept up to 2 examples for separate marks]			3	3		
				Question 5 total	**5**	**8**	**7**	**20**	**7**	**0**

2022

5. (a) The three springs, **A**, **B**, **C**, shown in the diagrams are identical and of negligible mass. Each spring has spring constant k.

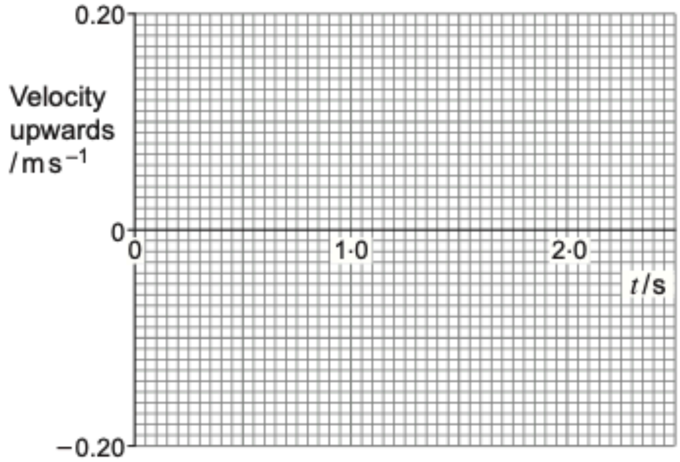


For the system on the left, the period of natural oscillations is T_1. For the system on the right, the period is T_2. Calculate the ratio $\frac{T_2}{T_1}$, giving your reasoning. [3]

(b) In a separate experiment a mass hanging from a spring is displaced **upwards** by 30 mm from its equilibrium position and released at time $t = 0$. It performs simple harmonic motion with a period of 1.20 s.

(i) Show that the maximum velocity of the mass is approximately $0.16\,\mathrm{m\,s^{-1}}$. [2]

(ii) **Sketch** a velocity-time graph for the mass **on the grid provided**. [2]



(iii) Calculate the speed of the mass at $t = 3.50$ s. [2]

(iv) Ursula thinks that the kinetic energy of the mass varies at a frequency of 1.67 Hz. Evaluate this claim. [2]

(c) Ursula modified the mass-spring system in part (b) so that its oscillations are significantly damped.

(i) Suggest what practical modification she might have made. [1]

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(ii) Ursula measured the amplitude of the oscillations at equal time intervals. Here are her results:

Amplitude / mm	30	24	19	15

Evaluate whether or not these results are consistent with an exponential decay of the amplitude. [2]

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(d) The physics of damping has been used in designing car suspensions and suspension bridges for pedestrians. Compare the **purposes** that damping serves in these two cases. [3]

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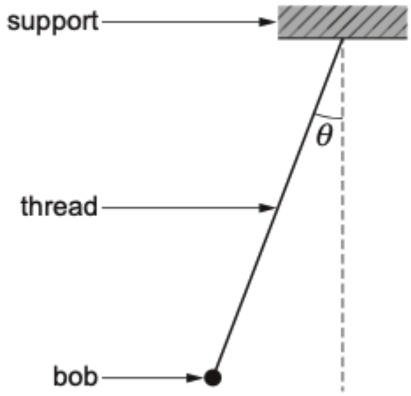
Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
5	(a)			Spring constant for two in series = $\frac{k}{2}$ (1) or by implication $T_2 = 2\pi\sqrt{\frac{2m}{k/2}}$ **or** equiv seen (1) **ecf** on k or $2k$ instead of $\frac{k}{2}$ $\frac{T_2}{T_1} = 2$ or equiv (1) [*No* ecf and *not* freestanding]	1	1 1		3	2	
	(b)	(i)		$\omega = \frac{2\pi}{1.20}$ [s^{-1}] = 5.24 s^{-1} or by impl (1) $v_{\text{max}} = 0.030\ [\text{m}] \times 5.24\ [\text{s}^{-1}]$ (1) $[= 0.16\ \text{m s}^{-1}]$		2		2	2	2
		(ii)		Sinusoid of period 1.2 s and peak value 0.16 m s^{-1} (1) Correct phase: inverted sine (1) N.B. one complete wave is sufficient	1	1		2	1	1
		(iii)		$v = -A\omega \sin \omega t = -0.157 \sin\left(\frac{2\pi}{1.20} \times 3.50\right)$ (1) v = 0.079 [m s^{-1} upwards] (1) [Accept 0.08 m s^{-1}] **Alternative:** $v = -0.03 \times \frac{2\pi}{1.20} \times \sin\left(\frac{2\pi}{1.20} \times 3.50\right)$ [m s^{-1}] or equv or by impl(1) v = 0.079 [m s^{-1} upwards] (1) [Accept 0.08 m s^{-1}] **Alternative:** Speed the same as at 1.1 s and 2.3 s (1) Speed = 0.08 [m s^{-1}] **ecf** on graph (1)	1	1		2	1	1

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
		(iv)		1.67 Hz shown to be twice the oscillation frequency or equivalent (1) This is right because v^2 has two [equal] positive peaks per oscillation cycle **or** equivalent (1)			2	2		2
	(c)	(i)		Attach piece of paper or similar. Accept surround with liquid			1	1		1
		(ii)		At least one ratio of successive amplitudes evaluated correctly (0.80, 0.79, 0.79 **or** 1.25, 1.26, 1.27) (1) Ratios compared and reasonable conclusion drawn (1) **Alternative:** Logs taken to any base (1) Δ (log A) shown to be almost equal (1)			2	2	2	2
	(d)			Car suspensions: suppresses [number of] oscillations (accept bounces) [caused by bumps etc in road surface] (1) Suspension bridges: Reduces amplitude of oscillations caused by pedestrians walking [Accept wind] (1) Further detail: e.g. bridge resonance with footfalls **or** car: mainly free oscs; but bridge: mainly forced oscs or critical damping reference for the car (1)			3	3		
				Question 5 total	**3**	**6**	**8**	**17**	**7**	**9**

2023

6. (a) A simple pendulum of length l consists of a small bob (a metal sphere) of mass m hanging by a light thread from a fixed support.



Show that when the pendulum is at a **small angle**, θ, to the vertical, the bob's acceleration, a, **in a direction at right angles to the thread** is approximately:

$$a = g\theta$$

You may add to the diagram. [3]

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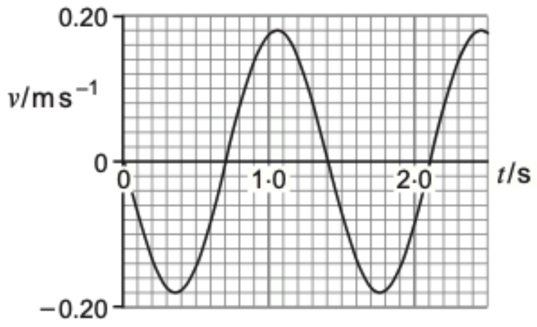
(b) A graph of velocity, v, against time, t, is given for a simple pendulum swinging through small angles.



(i) Show that the length of the pendulum is approximately 0.5 m. [3]

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(ii) The mass of the bob is 0.12 kg.

I. Show that the maximum kinetic energy of the bob is approximately 2 mJ. [2]

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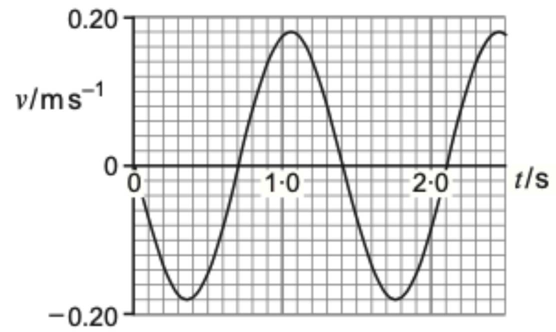
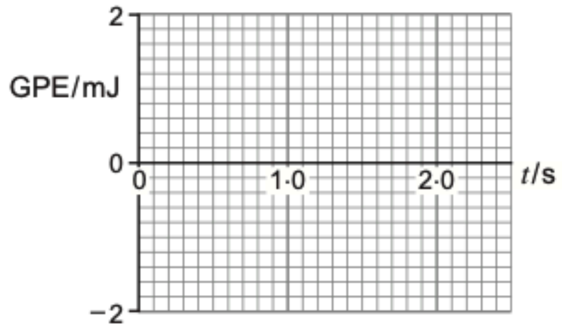
II. **On the blank grid, sketch a graph** of the bob's gravitational potential energy (GPE) against time (the upper graph is provided for reference). Take the GPE to be zero when the bob is at its lowest point. [3]





(iii) I. Calculate the centripetal acceleration of the bob at the bottom of its swing. [2]

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II. At the bottom of the swing the tension in the thread is greater than the weight of the bob. Explain why this is so. [2]

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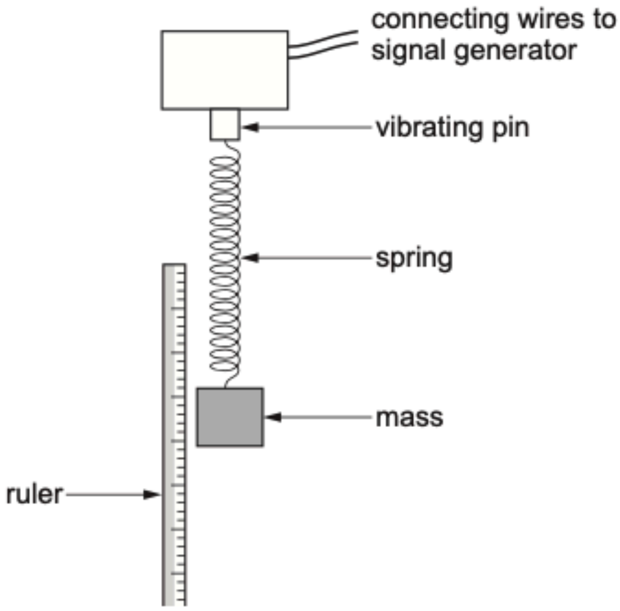
(c) Describe briefly how you would investigate **forced** oscillations using a mass and spring as the oscillating system, as in the set-up shown, and describe carefully what you would expect to find out about the amplitude of the forced oscillations. [6 QER]



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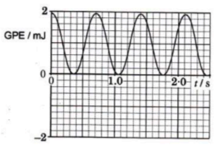
Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
6	(a)			Component of bob's weight at right angles to thread = $mg\sin\theta$ (1) $\sin\theta \approx \theta$ [since θ small] (1) Acceleration at right angles to thread = $\frac{mg\,[\sin]\,\theta}{m} = g\theta$ (1)		3		3	2	
	(b)	(i)		$l = \frac{T^2 g}{4\pi^2}$ i.e. rearrangement of the equation at any time (1) T = 1.4 [s] (1) l = 0.49 [m] (1) **Alternative:** $l = \frac{g}{\omega^2}$ (1) T = 1.4 [s] (1) l = 0.49 [m] (1)		3		3	2	
		(ii)	I.	$E_{\text{k max}} = \frac{1}{2} 0.12 \times 0.18^2$ [J] (1) = 1.94 m[J] (1)	1	1		2	1	
			II.	 Period (1) Phase (1) Shape non-pointy and maximum value correct to within a small square (1) If graph is negative then only the period mark can be awarded.	1 1	1		3	2	
		(iii)	I.	$a = \frac{0.18^2}{0.487}$ [m s^{-2}] (1) = 0.067 m s^{-2} (1) **unit mark** Accept use of 0.5 m leading to 0.065 m s^{-2}	1	1		2	1	

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
			II.	[Centripetal acceleration requires] resultant force on bob **/** $T - mg = ma$ (1) which must be upwards (1) Award 1 mark only for acceleration upwards	1	1		2		
	(c)			**Indicative content:** **Demonstrating forced oscillations** • With signal generator off, time 10 (say) oscillations to determine T and hence natural frequency $\left[\frac{1}{T}\right]$. • Set signal generator to a known frequency and read amplitude of oscillations of mass on ruler • Repeat over a range of frequencies [from near zero to well above system's natural frequency] • Additional detail, e.g. wait for steady oscillations **or** read limits of oscillations and divide by 2 (or equivalent) **or** do not adjust voltage output of signal generator between frequencies **or** use of mobile phone / recording device to record oscillations and use playback to determine amplitude. **Amplitude of the forced oscillations** • Low [but not zero] at very low frequencies • As frequency is increased, rises to a peak and then drops, approaching zero. • Peak occurs when signal generator frequency equals natural frequency • Known as resonance N.B. A sketched graph might be presented to support answer	3		3	6		6

2017

5. *(a)* Explain, in terms of molecules, how a gas exerts a pressure on the walls of its container, and why this pressure increases with temperature. [6 QER]

(b) A cylinder of volume $0.020\,m^3$ contains $0.091\,kg$ of nitrogen gas (relative molecular mass = 28) at a pressure of 3.9×10^5 Pa. Calculate:

(i) the rms speed of the molecules; [3]

(ii) the temperature of the gas. [3]

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Question			Marking details	Marks available				Maths	Prac
				AO1	AO2	AO3	Total		
5	*(a)*		**Indicative comments:** **A: Why the gas exerts a pressure** A1 Molecules collide with walls (or by implication). A2 Collisions exert (outward) forces on walls. A3 Molecules undergo changes in momentum [or in velocity or undergo acceleration] when colliding with walls. A4 Newton's third law applied correctly [even if not named] A5 Collisions distributed randomly over wall area. **Accept** reference to $p = \frac{F}{A}$. A6 Collisions between molecules and walls [on average] elastic **B: Why the pressure increases with temperature** B1 Mean KE of molecules [or rms speed, or mean speed or mean [magnitude] of momentum] increases with temperature. B2 Hence increases pressure [or force] exerted on walls. B3 On average each collision contributes more to pressure [or exerts greater force or has a greater momentum change] if molecules moving faster. B4 There'll also be more collisions per second if molecules are moving faster. **5-6 marks** Comprehensive account of why the gas exerts a pressure along with why pressure increases with temperature typically: Typical example A1 + A2 + A3 + (A4 or A5 or A6) B1 + B2 + (B3 or B4) *There is a sustained line of reasoning which is coherent, relevant, substantiated and logically structured.* **3-4 marks** Either comprehensive account of why the gas exerts a pressure or why pressure increases with temperature or account given of why the gas exerts a pressure and why pressure increases with temperature typically: Typical example A1 + A2 + (A3 or A4 or A5) B1 (but no mention of 'mean' needed) + B2 *There is a line of reasoning which is partially coherent, largely relevant, supported by some evidence and with some structure.*	6			6		

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
			1-2 marks Limited account of why the gas exerts a pressure and/or why pressure increases with temperature typically: Typical example A1, A2 B1 (but no mention of 'mean' needed) Any other point from A3, A4, A5, A6, B2 *There is a basic line of reasoning which is not coherent, largely irrelevant, supported by limited evidence and with very little structure.* **0 marks** *No attempt made or no response worthy of credit.*						
	(b)	(i)	$\rho = \frac{0.091}{0.020}\left[= 4.55\text{ kg m}^{-3}\right]$ **or** $Nm = 0.091\text{ [kg]}$ **or** by implication (1) $c_{\text{rms}} = \sqrt{\frac{3\times3.9\times10^5\times0.020}{0.091}}$ *or* $c_{\text{rms}}{}^2 = \frac{3\times3.9\times10^5\times0.020}{0.091}$ or by implic (1) [transposed and data inserted or vice versa] 510 m s^{-1} (1) Single arithmetical slips, including by a factor of 1 000, attract a 1 mark penalty. An error factor of N_A, (which may arise when $pV = \frac{1}{3}Nmc_{\text{rms}}^2$ is misapplied) loses 2 marks (error of principle).		3		3	3	
		(ii)	$n = \frac{91}{28} = [3.25\text{ mol}]$ **or** by implication (1) $T = \frac{3.9\times10^5\times0.020}{3.25\times8.31}$ **or** by implication **ecf** on n for this mark only (1) = 290 K **UNIT** (1)		3		3	3	
			Question 5 total	**6**	**6**	**0**	**12**	**6**	**0**

2018

7. *(a)* State **two** assumptions that must be made about the molecules of an ideal gas in order to derive the kinetic theory equation: [2]

$$p = \tfrac{1}{3}\rho\overline{c^2}$$

(b) A cylinder of volume 5.0×10^{-2} m^3 contains 2.20 mol of argon gas (relative molecular mass, M_r = 39.9) at a pressure of 250 kPa.

(i) Calculate the rms speed of the argon molecules. [3]

(ii) I. State what would happen to the rms speed if the kelvin temperature of the gas in the cylinder were doubled, justifying your answer. [2]

II. Explain briefly whether or not your answer to *(b)* (ii) I. would still apply if some gas escaped from the cylinder while the temperature was being raised. [1]

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
7	*(a)*			**Two × (1) from:** • Molecules [themselves] occupy negligible volume • Molecules exert negligible forces on each other except during collisions **or** move in straight lines between collisions • There is no preferred direction of molecular velocity **or** [directions of] motion are random **or** equivalent • Collisions are elastic [on average] • Collisions take negligible time or equiv, e.g. molecules are hard spheres	2			2		
	(b)	i		$\rho = \frac{2.2\times0.0399\text{ [kg]}}{0.050\text{ [m}^3]}$ or by implication (1) $c_{\text{rms}} = \sqrt{\frac{3p}{\rho}}$ or by implication (e.g. re-arrangement after data inserted). Mark can be given even if ρ is wrong (1) $c_{\text{rms}} = 654\text{ m s}^{-1}$ (1) Slips in $10^x \rightarrow -1$; incorrect $N_A \rightarrow 1_{max}$	1	1 1		3	2	
		ii	I	$\frac{1}{2}m\overline{c^2} = \frac{3}{2}kT$ used **or** KE proportional to T **or** equiv **or** by imp (1) c_{rms} goes up by [factor of] $\sqrt{2}$. (1) Accept $\sqrt{2} \times 654\text{ m s}^{-1}$ **or** 924 m s^{-1}	1	1		2	1	
			II	Yes, c_{rms} depends only on temperature, or equivalent		1		1		
				Question 7 total	**4**	**4**	**0**	**8**	**3**	**0**

2019

6. *(a)* Vadim uses a ruler to measure the sides of a copper block. He records the measurements as:

length = 50 ± 1 mm, breadth = 42 ± 1 mm, height = 36 ± 1 mm.

Using an electronic balance he measures the mass of the block as 670.85 ± 0.01 g.

Use Vadim's data to answer the following.

(i) Determine a value for the density of copper in $kg\,m^{-3}$ and the **absolute** uncertainty in this value. [4]

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(ii) Determine the number of atoms per m^3 of copper. The uncertainty is **not** required. The atomic mass of copper is 63.5 u. [2]

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(b) (i) I. Calculate the number of molecules per m^3 for a gas (assumed to be ideal) at a temperature of 15 °C and a pressure of 101 kPa. [3]

II. When asked why there are far fewer gas molecules per m^3 than atoms per m^3 in the copper block, a student replies, "Each molecule of the gas takes up much more space." Discuss whether or not he is right. [2]

(ii) I. Two gases have molecular masses $m_{(1)}$ and $m_{(2)}$. Show clearly that when the gases are at the same temperature, the ratio of the rms speeds of their molecules is: [2]

$$\frac{c_{\text{rms}(1)}}{c_{\text{rms}(2)}} = \sqrt{\frac{m_{(2)}}{m_{(1)}}}$$

II. Calculate the percentage difference in the rms speeds of nitrogen and oxygen molecules in the same sample of air. Take the percentage difference to be defined as:

$$\frac{\text{rms speed for nitrogen} - \text{rms speed for oxygen}}{\text{rms speed for oxygen}} \times 100\%$$

[Molecular mass for nitrogen = 28.0 u. Molecular mass for oxygen = 32.0 u.]
[2]

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Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
6	*(a)*	(i)		ρ correctly calculated ignoring sig figs, units, factors of 10^n [1] $\rho = 8.9 \times 10^3$ [kg m^{-3}] Accept $\rho = 8.87 \times 10^3$ [kg m^{-3}] [1] Percentage (or fractional) unc =0.07[2] (or 7[.2]%)] **or by implic** [1] $\rho = (8.9 \pm 0.6$ [or 0.7]$) \times 10^3$ [kg m^{-3}] **accept** $\rho = (8.87 \pm 0.64) \times 10^3$ [kg m^{-3}] [1]	1	1 1 1		4	2	4
		(ii)		Division of density by atomic mass even if error in units [1] 8.4×10^{28} [m^{-3}] **ecf** on ρ, no sig fig penalty [1]		2		2	1	2
	(b)	(i)	I	Correct transpos'n at any stage of $pV=nRT$ **or** $pV = NkT$ [1] Correct insertion of data, including T = 288 K in $pV = NkT$ **or** in $pV = nRT$ giving n = 42[.2] [mol] **or by implic** from N [1] $N = 2.5[4] \times 10^{25}$ [m^{-3}] [1]		3		3	2	
			II	Gas mainly empty space (between molecules) [but atoms packed/bonded together in solid] [1] Gas molecules are moving about at high speeds [so could be said to take up more space than vibrating atoms in solid] **or** molecules themselves are of comparable size [1]	1		1	2		
		(ii)	I	Correct use of $\frac{1}{2}mc_{\text{rms}}^2 = \frac{3}{2}kT$ or equivalent [1] Convincing algebra [1]	1	1		2		
			II	$\frac{c_{\text{rms}} \text{ for nitrogen}}{c_{\text{rms}} \text{ for oxygen}}$ =1.07 **or equiv or by implic** [1] 7 % [1]			2	2	1	
				Question 6 total	**3**	**9**	**3**	**15**	**6**	**6**

2022

6. (a) Define pressure. [1]

(b) A sealed canister contains 0.200 mol of oxygen (relative molecular mass: 32.0). An identical canister contains 0.200 mol of nitrogen (relative molecular mass: 28.0) at the same temperature. Giving your reasoning, determine these ratios:

(i) $\dfrac{\text{pressure of oxygen}}{\text{pressure of nitrogen}}$ [2]

(ii) $\dfrac{\text{rms speed of oxygen molecules}}{\text{rms speed of nitrogen molecules}}$ [2]

(c) (i) At the centre of the Sun the pressure is estimated to be 2.5×10^{16} Pa, and the density, $1.6 \times 10^{5}\,\text{kg m}^{-3}$. Calculate the rms speed of the particles in that region, treating them as molecules of an ideal gas. [2]

(ii) State **two** reasons why the ideal gas kinetic theory is not likely to give accurate results in this case. [2]

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
6	(a)			$\text{Pressure} = \frac{\text{[magnitude of normal]] force}}{\text{area [over which force acts]}}$	1			1		
	(b)	(i)		Ratio = 1.00 (accept 1) (or pressures are the same) (1) [Freestanding mark unless reasoning clearly wrong] Reasoning spelt out, e.g. because n, V, T the same in $pV = nRT$ or equivalent (1)		2		2		
		(ii)		Ratio = 0.94 [Accept 0.93 or 0.935 or $\sqrt{\frac{7}{8}}$ or equivalent] (1) Reasoning clearly based on $\frac{1}{2}m\overline{c^2} = \frac{3}{2}kT$ or $\left(\frac{1}{2}m\overline{c^2}\right)_{\text{O2}} = \left(\frac{1}{2}m\overline{c^2}\right)_{\text{N2}}$ (1)		2		2	1	
	(c)	(i)		$\overline{c^2} = \frac{3\times2.5\times10^{16}}{1.6\times10^5}$ [$= 4.69 \times 10^{11}$ m^2 s^{-2}] (1) [transp & subst] c_{rms} = 6.8 × 10^5 [m s^{-1}] (1)		2		2	1	
		(ii)		**Any 2 × (1) from:** • Particles take up space **or** little space between particles • Forces between particles not negligible • More than one sort of particle present **or** accept: no molecules at the centre of the Sun • Collisions likely to be inelastic	2			2		
				Question 6 total	**3**	**6**	**0**	**9**	**2**	**0**

2023

7. (a) Explain why, according to the kinetic theory, a gas exerts a pressure on the walls of its container. You will need to use the idea of momentum as well as that of pressure. [3]

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(b) At one instant, three molecules in a sample of a gas have speeds in $\mathrm{m\,s^{-1}}$ of 394, 453 and 527. Calculate their rms speed. [2]

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(c) The speed of sound, v_s, in nitrogen at three temperatures is given below.

Temperature / K	100	200	300
v_s / m s^{-1}	204	288	353

There is a simple mathematical relationship between v_s and c_{rms}, the rms speed of nitrogen molecules at the same temperature. Determine this relationship, showing your reasoning. (Relative molecular mass of nitrogen molecule = 28.) [4]

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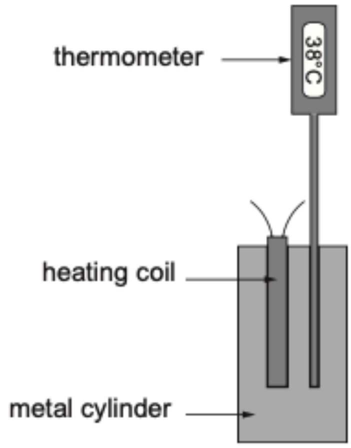
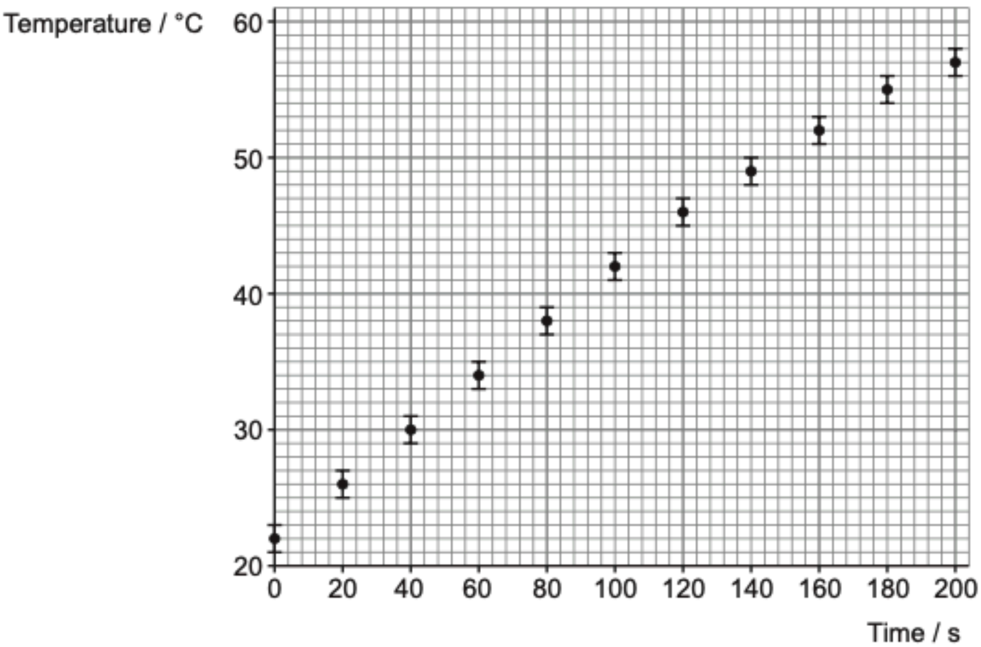
Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
7	(a)		Molecules hit {walls / container} (1) Momentum change of molecule that occurs [is away from wall], so molecule exerts an [outward] force on the wall (1) Such forces over an area give rise to the pressure (1) accept reference to $p = \frac{F}{A}$	3			3		
	(b)		Division of ($394^2 + 453^2 + 527^2$) by 3 and square-rooting **or by implication** [638174 ÷ 3 = 212 725; $\sqrt{212725} = 461$] Tolerate slips if correct procedure apparent, for this mark only (1) $c_{\text{rms}} = 461[\text{m s}^{-1}]$(1)		2		2	2	
	(c)		c_{rms} evaluated at one temperature (1 mark method, 1 mark answer) At 100 K, $c_{\text{rms}} = \sqrt{\frac{3\times1.38\times10^{-23}\times100}{28\times1.66\times10^{-27}}}$ **or** $\sqrt{\frac{3\times8.31\times100}{0.028}} = 298\ [\text{m s}^{-1}]$ **or**, at 200 K, $c_{\text{rms}} = \sqrt{\frac{3\times1.38\times10^{-23}\times200}{28\times1.66\times10^{-27}}}$ **or** $\sqrt{\frac{3\times8.31\times200}{0.028}} = 422\ [\text{m s}^{-1}]$ **or**, at 300 K $c_{\text{rms}} = \sqrt{\frac{3\times1.38\times10^{-23}\times300}{28\times1.66\times10^{-27}}}$ **or** $\sqrt{\frac{3\times8.31\times300}{0.028}} = 517\ [\text{m s}^{-1}]$ Ratios v_s / c_{rms} or c_{rms} / v_s evaluated at the **three** temperatures, giving 0.68 or 1.46 but **ecf** on c_{rms} values (1) **Conclusion:** ratio is constant or proportional or equations seen (1) Award a maximum of 3 marks if only **two** temperatures considered. Award a maximum of 2 marks for use of $c_{\text{rms}} \propto \sqrt{T}$ and ratios of $\frac{v_s}{\sqrt{T}}$ calculated for all **three** temperatures			4	4	4	
			Question 7 total	**3**	**2**	**4**	**9**	**6**	**0**

2017

6. *(a)* Alice performs an experiment to determine the specific heat capacity, c, of a metal in the form of a cylinder with holes drilled in it for a heating coil and a thermometer. She determines the mass, m, of the cylinder using a digital balance. Alice sets up a circuit to provide constant power to the heating coil and to enable the pd, V, across it and current, I, through it to be measured. The graph of temperature against time for the cylinder, as well as her other measurements, are given below.

m = 0.570 kg, V = 12.20 V, I = 3.81 A





(i) Draw a circuit diagram of the circuit required. [Show the heating coil as a resistor.] [2]

(ii) Suggest why the points for the highest temperatures show significant deviations from the trend of the points at lower temperatures, and what could have been done to reduce the deviation. [2]

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(iii) **Using an appropriate portion of the graph**, determine the maximum gradient and the minimum gradient. [4]

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(iv) Show clearly that the graph gradient should be:

$$\text{gradient} = \frac{VI}{mc}$$ [2]

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(v) Hence determine a value for the specific heat capacity of the metal of the cylinder, together with its **absolute uncertainty**. Assume that the percentage uncertainties in m, V and I are negligible. [5]

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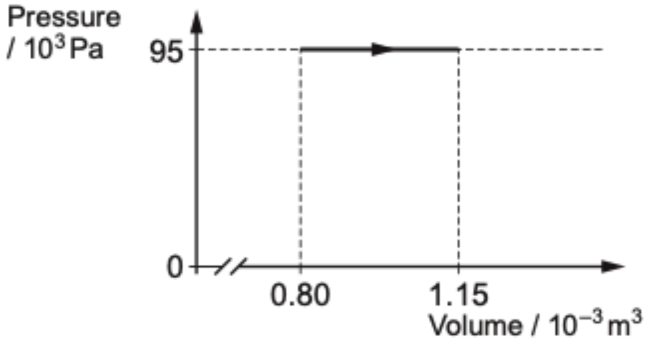
(b) In another experiment, 0.031 mol of helium (a monatomic gas) is heated so that it expands at constant pressure (see diagram). Its temperature rises from 295 K to 424 K.



(i) Calculate the heat flow into the gas during this change. [3]

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(ii) Discuss whether or not this amount of heat would be needed in all circumstances to raise the temperature of 0.031 mol of helium from 295 K to 424 K. [2]

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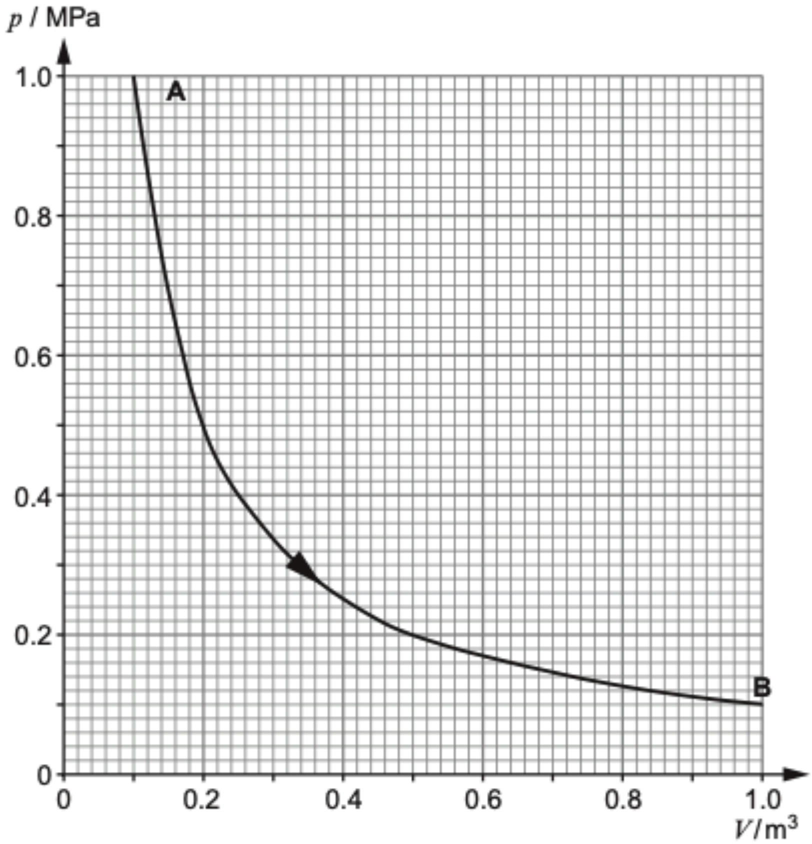
Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
6	*(a)*	(i)	Circuit that will supply power to heating coil. Accept cell or battery symbol for power supply or unclear symbol for power supply if labelled. (1) Ammeter and voltmeter correctly connected. (1)	2			2		2
		(ii)	Heat loss [begins to show at higher temperatures] (1) Insulate (lag) the cylinder (1)			2	2		2
		(iii)	Reasonable max gradient line drawn through error bars and triangle or pair of points ≥ half grid width shown (1) Same for min gradient (1) Maximum gradient between 0.200 and 0.230 [°C s^{-1}] (1) Minimum gradient between 0.170 and 0.190 [°C s^{-1}] (1) No sig fig penalty		4		4	4	4
		(iv)	$VIt = mc\,(\theta - \theta_0)$ or $VI(\Delta)t = mc\,\Delta\theta$ (1) $\theta = \frac{VI}{mc}t + \theta_0$ or $\frac{\Delta\theta}{\Delta t} = \frac{VI}{mc}$ (1) [Hence gradient = $\frac{VI}{mc}$]		2		2	2	2
		(v)	Values of V, I, m and gradient(s) (max and min or mean) put into $c = \frac{VI}{m \times \text{gradient}}$ **or** by implication (1) Mean of extreme gradients taken **or** mean of extreme c values. (**ecf** on values whose mean is taken; this is a process mark) No sig fig penalty (1) Mean c value consistent with gradients and to **max of 3 sig figs** (**ecf**) and with correct **units** [e.g. 448 J kg^{-1} °C^{-1}or 450 J kg^{-1} °C^{-1}] (1) Extreme gradients put into % unc equation **or** half range of extreme c values calculated or by implication (1) Value of absolute unc evaluated correctly to 1 sig fig **ecf** (1) Accept 2 sig figs	1 1	1 1 1		5	5	5

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
	(b)	(i)	$\Delta U = \frac{3}{2} \times 0.031 \times 8.31 \times (424 - 295)$ [J] or by implication [ΔU = 49.85 J](1) $W = 95 \times 10^3 \times (1.15 - 0.80) \times 10^{-3}$ [J] or by implication [W = 33.3 J] (1) $Q = 83$ [J] **ecf** on ΔU or W (1)	1 1	1		3	3	3
		(ii)	Heat inflow depends on work done [as well as temperature rise] or equivalent (1) Work related to volume change e.g. [if no volume change no work done] (1)			2	2		2
			Question 6 total	**6**	**10**	**4**	**20**	**14**	**20**

2018

8. *(a)* 33.2 mol of nitrogen gas is contained in a cylinder fitted with a piston. The gas is allowed to expand from A to B, doing work against the piston. A p–V graph for the expansion is given below.



(i) Show that the expansion occurs at a constant temperature of approximately 360 K. [3]

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(ii) Determine the approximate amount of work done by the gas during the expansion. [2]

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(iii) Rini claims that the work done by the gas results in an equal amount of internal energy being lost by the gas. Give the *correct* application of the first law of thermodynamics to this isothermal expansion. [2]

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(b) An estimated 600 MJ of work can be produced by an ordinary car engine burning 0.10 m^3 (100 litre) of petrol. An estimated 15 MJ of work can be produced by the expansion of the same volume of air compressed to the highest safe (initial) pressure.

Discuss the advantages and disadvantages of powering cars by compressed air rather than petrol. Calculations are not required. [3]

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Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
8	*(a)*	(i)	pV evaluated (or equivalent) at two or more points, at least one of which isn't at an extreme end of the curve (1) Conclusion correctly argued (for example, constant pV implies constant temperature) or simply finding equal temps from two points. [For this mark accept both extremes, A and B.] (1) T = 362 K (1)			3	3	2	
		(ii)	Reasonable method used to find 'area' under graph (1) W = 230 [± 50] kJ (1)	1	1		2	1	
		(iii)	Internal energy doesn't change [as temp doesn't change significantly] , [accept ΔU = 0] (1) But an amount of heat flows <u>into</u> the system equal to work done [by the gas] (1)			2	2		
	(b)		1 mark each for up to two 'isolated' points such as • Compressed air car can't go as far per 'fill' / lower range • Compressed air car won't pollute [locally] [accept cleaner power source] • Car may be quieter running off compressed air 1 extra mark available for developing the first bullet eg ... Car has to do work against resistive forces (and sometimes against pull of gravity) hence use of fuel, compressed air etc. Car won't go [nearly] as far on *same volume* of compressed air as petrol or much larger compressed air storage vessel will be needed than petrol tank for car to be able to go as far. 1 extra mark available for developing the second bullet... Car won't pollute But work (or energy) needed to compress the gas Probably involves burning fuel in a power station			3	3		
			Question 8 total	**1**	**1**	**8**	**10**	**3**	**0**

2019

7. *(a)* State what is meant by the *heat*, Q, entering a system. [2]

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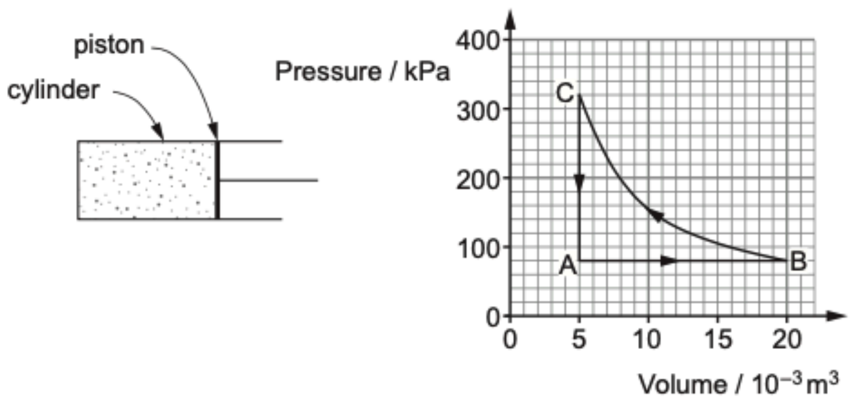
(b) A gas (assumed ideal) is contained in a cylinder with a moveable, leak-proof piston. The gas is taken through the cycle ABC shown on the graph. The stage BC takes place at constant temperature.



(i) Calculate the work done by the gas in the stage AB. [2]

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(ii) For each of the stages AB, BC and CA separately, **and** for the cycle as a whole, use the first law of thermodynamics to explain whether heat flows into the system or out of the system. Calculations are **not** required. [6 QER]

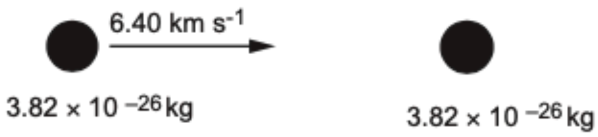
Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
7	*(a)*			Energy [entering system] [1] by virtue of a temperature difference [or equivalent] [1]	2			2		
	(b)	(i)		Correct substitutions (ignoring power of 10) into $W = p\Delta V$ [1] W = 1.20 k[J] [1]	1	1		2		
		(ii)		**Indicative content:** **AB** Gas does work [or W positive] **and** internal energy rises [or ΔU positive] since temp rises [as gas expands at constant pressure]. So heat flows in [or Q positive] **BC** Gas has work done on it [or W negative]. No change in internal energy [or ΔU =0] so heat out [or Q negative] **CA** No work [or W = 0] but internal energy falls [or ΔU negative] so heat out [or Q negative] **ABCA** Net work done on gas [or W negative], no change in internal energy [or ΔU =0] so heat out [or Q negative] **5-6 marks** They have considered Q, W and ΔU well for all stages. *There is a sustained line of reasoning which is coherent, relevant, substantiated and logically structured.* **3-4 marks** They have considered 2 of Q, W and ΔU well for all stages. Or they have attempted to consider Q, W and ΔU for most stages. *There is a line of reasoning which is partially coherent, largely relevant, supported by some evidence and with some structure.*	6			6		

2020

5. *(a)* (i) Show that the mean kinetic energy of (monatomic) gas molecules at a temperature of 1 500 K is approximately 3×10^{-20} J. [2]

(ii) At 1 500 K, sodium is a gas of monatomic molecules, each of mass 3.82×10^{-26} kg. Calculate their rms speed. [2]

(b) A sodium molecule moving at $6.40\,\text{km}\,\text{s}^{-1}$ to the East collides with an almost stationary sodium molecule.



(i) Discuss whether a molecule with a speed of $6.40\,\text{km}\,\text{s}^{-1}$ could be present at some instant in sodium gas at 1 500 K and, if so, how it could have acquired this speed. [3]

(ii) After the collision one of the two molecules is moving to the East at $4.39\,\text{km}\,\text{s}^{-1}$. Calculate the speed and direction of motion of the other molecule. [2]

(iii) Determine whether or not the collision is elastic. [3]

(iv) Explain how Newton's 3rd law applies to the collision. [1]

(v) Soon after the collision in *(b)*, one of the molecules gives out a photon of wavelength 589 nm. Evaluate whether or not the momentum of the photon significantly affects the molecule's velocity. [3]

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
4	(a)			Distance up ramp = $\frac{1.10\text{ m}}{\sin 15°}$ [= 4.25 m or by implic] [1] Power in = $\frac{960\text{ N} \times 4.25\text{ m}}{35\text{ s}}$ **ecf on 4.25 m** [1] = 117 [W] **no ecf** [1]		3		3	2	
	(b)			Grav PE gained by piano = 320 × 9.81 × 1.10 [J] [= 3.45 kJ] or by implication [1] Efficiency = $\frac{3453}{960 \times 4.25} \times 100\ \%$ **[ecf on top or bottom]** [1] or Efficiency = $\frac{99\text{ [W]}}{117\text{ [W]}} \times 100\ \%$ **[ecf on top or bottom]** = 85 [%] or 0.85 **no ecf** [1]		3		3	2	
	(c)			KE of piano ≅ $\frac{1}{2} \times 320 \times \left(\frac{4.25}{35}\right)^2 = 2.4\text{ J}$ [1] Negligible compared with hauling work [or] GPE gained, so *not* a major cause of inefficiency [1] **Alternative answer** KE got back at the end of the process... [1] ... as piano comes to rest if hauling stopped a little before required height rise [1]			2	2	1	
				Question 4 total	**0**	**6**	**2**	**8**	**5**	**0**

6. *(a)* (i) A cylinder of gas fitted with a pressure gauge is surrounded by melting ice. The gas pressure stabilises at 96 kPa. The cylinder is then surrounded instead by boiling water. The pressure stabilises at 131 kPa. Show that this is consistent with a value of –273 °C for the absolute zero of temperature. [3]

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(ii) State the significance, in terms of molecules, of the absolute zero of temperature. [1]

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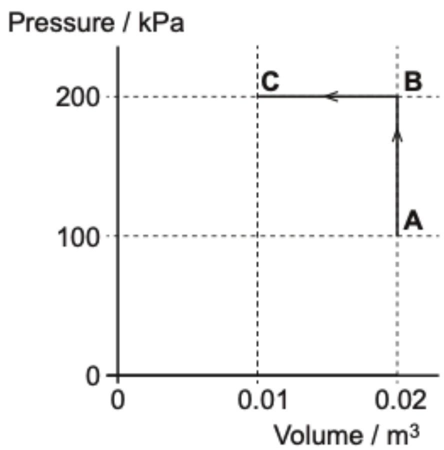
(b) A cylinder with a moveable, leak-proof piston contains 0.850 mole of an ideal gas. The gas is taken along the path **ABC** shown on the p–V grid.



(i) Show clearly that the gas is at the same temperature at **A** and **C**, and determine this temperature. [3]

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(ii) Calculate the work done on the gas over **ABC**. [2]

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(iii) Determine the net heat flow over **ABC**, stating whether it is in or out of the system, **and** justifying your answer clearly in terms of the *1st law of thermodynamics.* [3]

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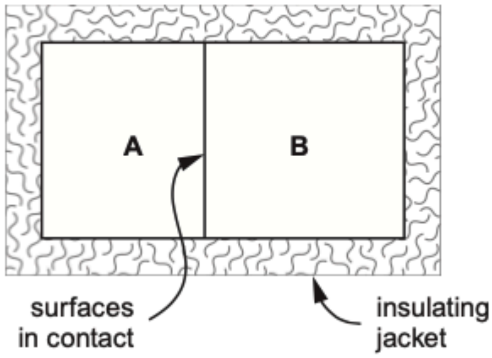
Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
6	(a)	(i)		Ice at 0 °C, boiling water at 100 °C or by implication [1] A correct strategy, e.g. comparing $\frac{131}{96}$ with $\frac{373}{273}$ [1] Convincingly carried through, e.g. $\frac{131}{96} = 1.36$, $\frac{373}{273} = 1.37$ [1] **Alternative:** $\frac{p}{T} = \frac{nR}{V}$ = constant if V of cylinder is constant (1) $\frac{96}{T} = \frac{131}{(T+100)}$ (1) So $35T$ = 9 600 and T = 274 [K] so absolute zero = –274 [°C] (1)	1	1 1		3	1	3
		(ii)		At absolute zero the energy of particles in a body is the lowest it can possibly be, or equivalent	1			1		
	(b)	(i)		pV is the same at A and C so temperature the same or equiv [1] $T = \frac{200000 \times 0.01}{0.85 \times 8.31}$ **transposed** or by impl [1] $T = 283$ [K] **no ecf** [1]		3		3	2	
		(ii)		Work over AB = 0. Work over BC = [–] 200 000 × 0.01 J or by implication [1] Work on gas = 2 000 [J] [1]		2		2	1	

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
		(iii)		A and C at same temp so [for ideal gas] $\Delta U = 0$ [1] So heat out = Work in **or** $Q = \Delta U + W = 0 + (-2000\text{ J})$ [1] So 2000 [J] of heat flows out [1]	1	1 1		3	1	
				Question 6 total	**3**	**9**	**0**	**12**	**5**	**3**

7. Two copper blocks, **A** and **B**, are placed in contact and the assembly is covered by a thermally insulating jacket. **Initially A is at a higher temperature than B.**



Describe what happens over a period of time, in terms of heat, internal energy, temperature **and** the motion of copper atoms. [6 QER]

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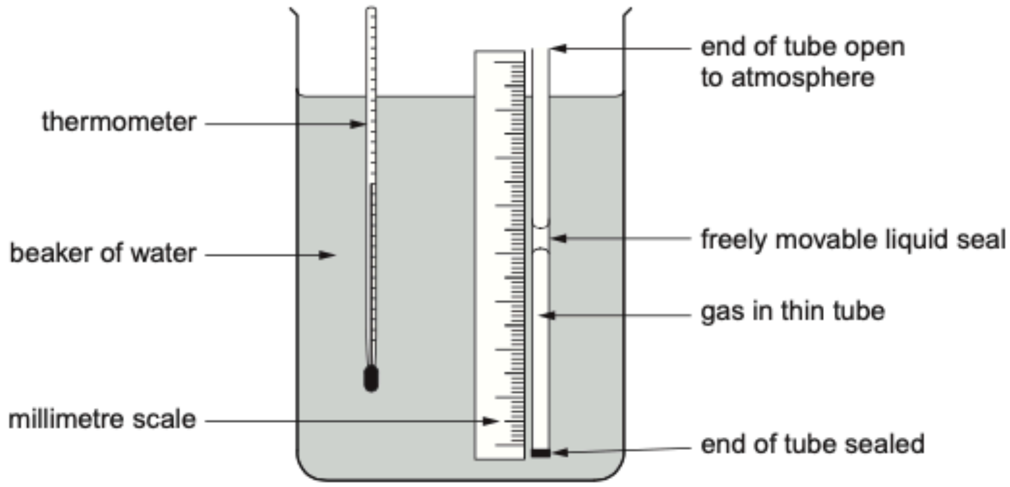
Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
7				**Indicative content** **Heat** • No heat flow in or out of system as a whole • flows from A to B • flow rate decreases • eventually no flow **or** flow rate approaches zero **Internal energy** • A's decreases, B's increases • Rates of decrease or increase eventually approach zero. **Temperature** • A's decreases, B's increases • Temps of A and B approach [accept *reach*] a common value. **Motion of atoms** • Atoms are *vibrating*. • Motion correctly associated with temperature. Accept with internal energy.	6			6		

2021

6. *(a)* The diagram shows apparatus that may be used to estimate the absolute zero of temperature, in °C, by investigating the expansion of a gas at constant pressure.



Describe the method you would follow and how you would use your results to obtain a value for the absolute zero of temperature, in °C. [6 QER]

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(b) (i) One assumption of the kinetic theory of ideal gases is that a gas consists of particles (molecules) in rapid random, translational, motion. State **two** other assumptions of the ideal gas theory. [2]

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(ii) A cylinder of volume $0.050\,m^3$ contains 20.0 mol of oxygen gas at a pressure of 1.00×10^6 Pa. [Relative molecular mass of oxygen = 32.0.]

I. Calculate the rms speed of the molecules. [3]

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II. The oxygen in the cylinder is now replaced by 20.0 mol of helium [relative molecular mass = 4.0] at the same temperature. Ciaran claims that both the pressure and the rms speed of the molecules will be the same as in the previous part. Evaluate both of these claims. [4]

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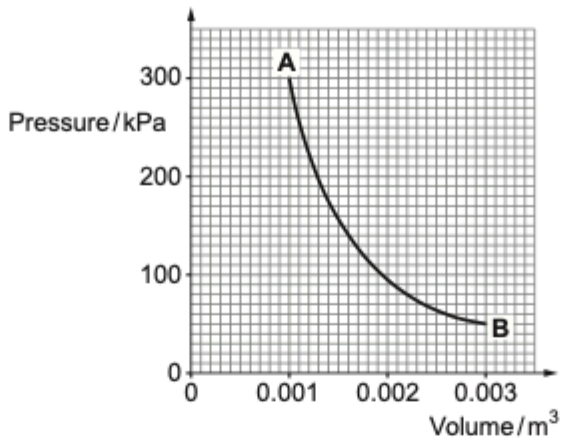
Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
6	*(a)*			**Indicative content:** **Using the apparatus** • Cool with ice cubes, then heat [gradually] to 100 °C • Heat with Bunsen **or** immersion heater • Record temp and length, *l*, of trapped gas, • at roughly equal temperature intervals • Stir • Allow to reach equilibrium **Determining absolute zero** • Plot *l* against [Celsius] temperature, • with temperature axis extending down to –300 °C • Draw [best] straight line through points • Where line cuts temperature axis is absolute zero [in °C] A sketched graph might be presented to support answer; check that each bullet above is explicitly covered. **5-6 marks** Comprehensive description of both the method and the analysis. *There is a sustained line of reasoning which is coherent, relevant, substantiated and logically structured.* **3-4 marks** Comprehensive description of either the method or the analysis or a limited description of both. *There is a line of reasoning which is partially coherent, largely relevant, supported by some evidence and with some structure.* **1-2 marks** Limited description of either the method or the analysis. *There is a basic line of reasoning which is not coherent, largely irrelevant, supported by limited evidence and with very little structure.* **0 marks** No attempt made or no response worthy of credit.	6			6		6

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
	(b)	(i)		**Any 2 × (1) from:** • Forces between molecules negligible [except during collisions] **or** molecules travel in straight lines between collisions • Molecules occupy a negligible volume • Collisions are [on average] elastic - Collisions take negligible time	2			2		
		(ii)	I	Correct handling of N, m and V, for example to produce $\rho = \left[\frac{20.0\times32.0\times10^{-3}}{0.050}\ \text{kg m}^{-3}\right]$ [= 12.8 kg m^{-3}] or by implication [1] Transposition: $\overline{c^2} = \frac{3p}{\rho}$ or equivalent) [1] c_{rms} = 484 [m s^{-1}] [1]		3		3	2	
			II	$p = \frac{nRT}{V}$ and everything on the right is the same (or equiv) [1] Therefore Ciaran is right about *pressure* [not free-standing] [1] $\frac{1}{2}m\overline{c^2} = \frac{3}{2}kT$ [1] Right hand side same, but m smaller for He, so c_{rms} must be larger. Accept calculation of the new speed. Ciaran wrong. [1] **Alternative answer for c_{rms}** For the He, p is the same but ρ is smaller in $\overline{c^2} = \frac{3p}{\rho}$ or $c_{rms} = \sqrt{\frac{3p}{\rho}}$ [1] So c_{rms} is larger and Ciaran is wrong over this [1] Penalise absence of right/wrong only once.			4	4	1	
				Question 6 total	**8**	**3**	**4**	**15**	**3**	**6**

7. An insulated cylinder fitted with a leak-proof piston contains 0.125 mol of helium gas.

The piston is now allowed to move, so that the gas expands quickly from point **A** to point **B**, as shown. No heat enters or leaves the gas during the expansion.



(a) Calculate the temperatures of the gas at **A** and at **B**. [3]

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(b) Use the graph to determine (approximately) the work done by the expansion. [2]

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(c) Use the *first law of thermodynamics* to explain why a fall of temperature is to be expected over **AB**. [2]

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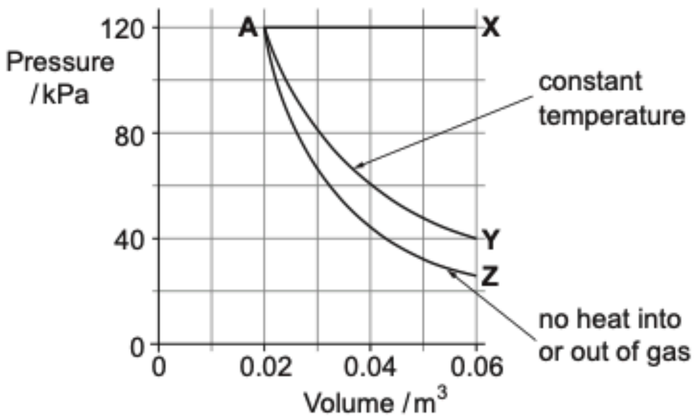
Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
7	(a)		$T_A = \frac{300\times10^3\times0.001}{0.125\times8.31}$ [K] **or** $T_B = \frac{50\times10^3\times0.003}{0.125\times8.31}$ [K] or by implication [1] $T_A = 289$ K [1] $T_B = 144$ K [1] **ecf** if *same* slip		3		3	2	
	(b)		Squares under graph counted or area under graph calculated by some other method, tolerating slips, e.g. in factor of 10^3 [1] 230 J [±30 J] [1]		2		2	1	
	(c)		Gas does work, no heat comes in, so internal energy drops **or** $\Delta U = Q - W$ with $Q = 0$ and $W > 0$ [1] Drop in internal energy implies drop in temperature [for an ideal gas] [1]		2		2	1	
			Question 7 total	**0**	**7**	**0**	**7**	**4**	**0**

2022

7. The diagram shows three ways (AX, AY and AZ) in which 0.90 mol of an ideal gas can expand from a volume of $0.020\,m^3$ to a volume of $0.060\,m^3$.



(a) Calculate the temperatures at **A** and at **X**. [3]

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(b) Calculate the work done over **AX**. [2]

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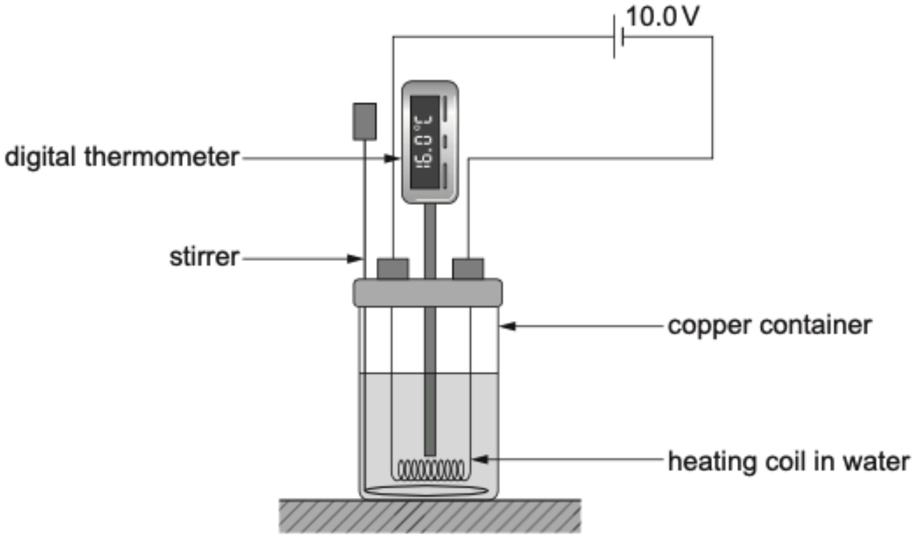
(c) For both AY and AZ compare the work done, internal energy change and heat flow **with those for AX**. Calculations are not wanted, but you must give your reasoning. [6 QER]

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
7	(a)			$T_A = \frac{120000 \times 0.020}{0.90 \times 8.31}$ [K] or $T_X = \frac{120000 \times 0.060}{0.90 \times 8.31}$ [K] (1) or by impl $T_A = 321$ K (1) $T_X = 963$ K (1) **unit (max penalty–1)**	1	 1 1		3	2	
	(b)			W = 120 000 × 0.040 J (1) [Tolerate wrong powers of 10] W = 4.8 k[J] (1)	1	1		2	1	
	(c)			**Indicative content:** **AY compared to AX** **WORK -** Less work done by the gas as area under curve smaller. ***U*** - No change in *U* as temperature constant ... whereas for AX *U* increases as temperature increases. **HEAT -** Heat input less than for AX from first law of thermodynamics. Specifically because both W and ΔU less than for AX **AZ compared to AX** **WORK -** Less work done by the gas as area under curve smaller. Even less work than for AY ***U*** - *U* decreases according to 1st law of thermodynamics, specifically because work is done but no heat in. [But for AX, *U* increases, as temp increases]. Decrease in *U* corresponds to *drop* in temperature	2	4		6		

2023

2. (a) Zayn uses a 4.2 cm length of nichrome wire to create a heating coil. The wire has a diameter of 0.12 mm and a resistivity of $1.2 \times 10^{-6}\ \Omega\,\text{m}$. Show that the rate of energy transfer by the heater when operating at 10.0 V is approximately 20 W. [4]

(b) The heating coil is used inside a copper container to determine the specific heat capacity of water using the apparatus below.



(i) Define the specific heat capacity of a material. [2]

(ii) The heating coil is switched on for 5.0 minutes before being switched off. Use the following information to determine the specific heat capacity of water: [3]

Mass of copper container = 0.080 kg

Specific heat capacity of copper = 380 $J\,kg^{-1}\,°C^{-1}$

Volume of water = 190 cm^3

Density of water = 0.997 $g\,cm^{-3}$

Temperature rise = 8.0 °C

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(iii) Zayn repeated the experiment and noted that the room temperature was 16.0 °C. Before he started the heating process, he cooled the apparatus to 12.0 °C in a refrigerator. Discuss whether this is good experimental practice. [2]

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Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
2	(a)		Substitution into $R = \frac{\rho l}{A}$ (1) even if slips in factors of 2 or 10 R = 4.5 [Ω] (1) Use of $P = \frac{V^2}{R}$ or alternatives (1) P = 22.4 [W] **ecf** on R (1)	1 1	1 1		4	3	
	(b)	(i)	The energy required to raise [the temperature of] 1 kg (1) by 1 °C or K (1)	2			2		2
		(ii)	$E = Pt = 22.4 \times 5 \times 60 = 6\,720$ [J] **and** $M = \rho V = 0.997 \times 190 =$ 189.4 [g] (1) $E_{\text{delivered}} = E_{\text{into copper container}} + E_{\text{into water}}$ i.e. $6\,720 = (0.08 \times 380 \times 8) + (0.1894 \times c_w \times 8)$ (1) **ecf** for slips in E and M $c_w = 4\,275$ [J kg^{-1} °C^{-1}] (1) **Alternatively, if 20 W is used** $E = Pt = 20 \times 5 \times 60 = 6\,000$ [J] **and** $M = \rho V = 0.997 \times 190 =$ 189.4 [g] (1) $E_{\text{delivered}} = E_{\text{into copper container}} + E_{\text{into water}}$ i.e. $6\,000 = (0.08 \times 380 \times 8) + (0.1894 \times c_w \times 8)$ (1) **ecf** for slips in E and M $c_w = 3\,800$ [J kg^{-1} °C^{-1}] (1)		3		3	3	3
		(iii)	[During the heating process below 16 °C] heat will be absorbed from surrounding air / room (1) and above 16 °C heat will be emitted to surrounding air so balanced, method minimises heat losses so good practice (1)			2	2		2
			Question 2 total	**4**	**5**	**2**	**11**	**6**	**7**

4. (a) The first law of thermodynamics may be written as:

$$\Delta U = Q - W$$

A student **incorrectly** defines the terms from the first law of thermodynamics as shown below:

ΔU Increase in temperature
W Work done
Q Heat in a system

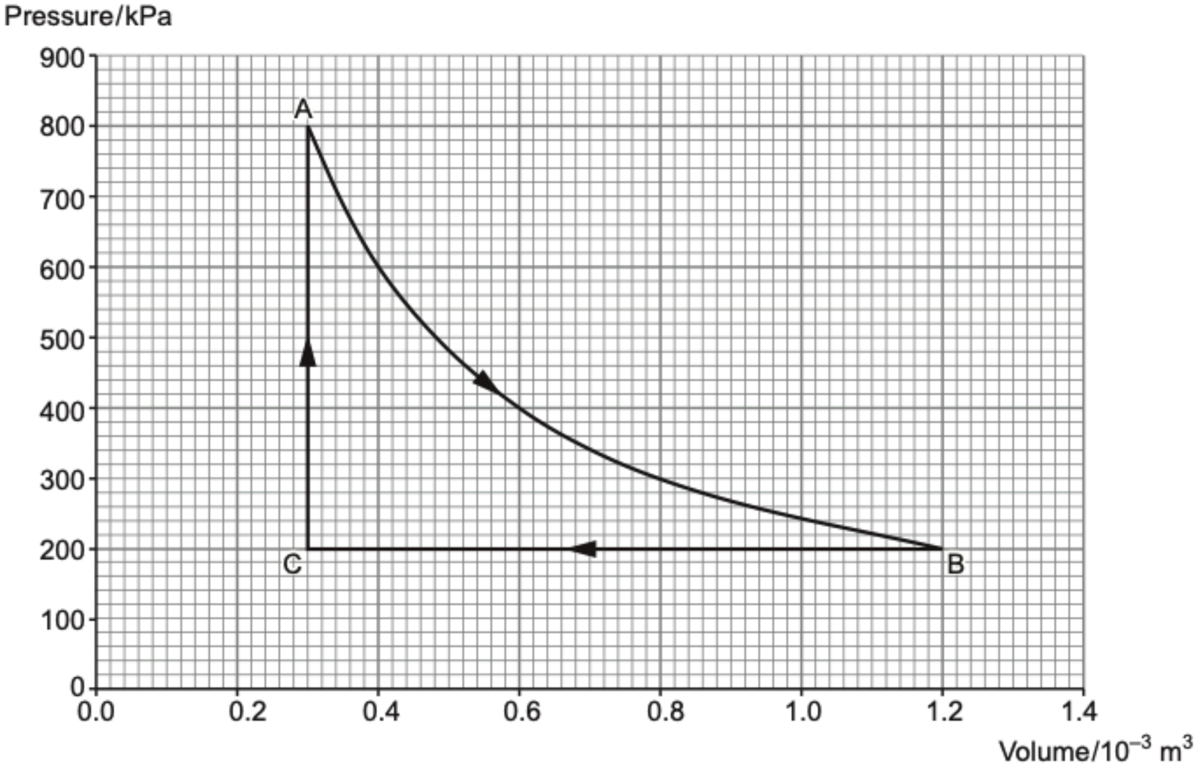
In each case, write the correct definition for the term. [3]

ΔU ....

W ....

Q ....

(b) A cylinder with a leak proof piston contains 0.10 mol of an ideal monatomic gas. The gas is taken through the following processes that result in changes in pressure and volume, as shown in the graph below.



(i) Confirm that the process A → B is isothermal (i.e. it takes place at a constant temperature). [2]

(ii) Show that the work done during the process A → B is approximately 330 J. [2]

(iii) Joseph considers the whole process A → B → C → A. He calculates the heat flow into the system to be 150 J. Grace disagrees, and states that 150 J of heat would flow out of the system. Determine if either Joseph or Grace is correct. [3]

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
4	(a)		ΔU - Increase (accept change) in internal energy (1) W – Work done <u>by</u> the system (1) Q – Heat [flow] <u>into</u> the system (1)	3			3		
	(b)	(i)	Use of pV = constant **OR** internal energy calculated **OR** temperatures calculated (1) Showing that two or more values are constant (1)		2		2	2	
		(ii)	**Any ×(1) from:** • Counting squares method • Single trapezium method • Multiple trapezia method Value = (333 ± 20) [J] (1)		2		2	2	
		(iii)	$\Delta U = 0$ for A → B → C → A (1) $Q = \Delta U + W$ therefore $Q = W$ (1) Net W = + 330 – 180 = +150 [J] therefore Joseph is correct (1)			3	3	1	
			Question 4 total	**3**	**4**	**3**	**10**	**5**	**0**