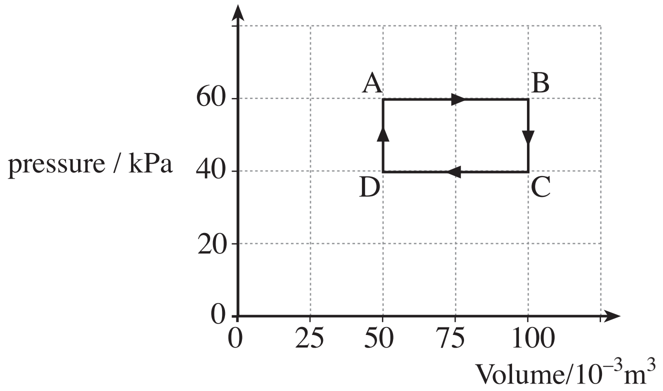
IGC HK EXAM - WJEC

WJEC & Eduqas - Physics

Mock 1 Practice Paper - Question You Must Do

Examiner only

4. A gas undergoes a thermodynamic cycle, ABCDA, as shown in the p-V diagram.



(a) The first law of thermodynamics can be written in the form $\Delta U = Q - W$

Sate the meaning of **each** term. [2]

ΔU ....

Q ....

W ....

(b) (i) Calculate the work done by the gas during process AB. [2]

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(ii) The temperatures at point A and B are 278 K and 556 K respectively and the amount of gas is 1·3 moles. The internal energy of the gas is given by the equation $U = \frac{3}{2}nRT$.

Calculate the **change** in internal energy of the gas during the process AB. [2]

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(c) (i) How much work is done during process BC? [1]

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(ii) Describe and explain the heat flow during the process BC (no calculations are required). [2]

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(d) (i) Explain why the change in internal energy over the closed cycle ABCDA is zero. [1]

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(ii) Calculate the net heat supplied to the gas over the cycle ABCDA. [3]

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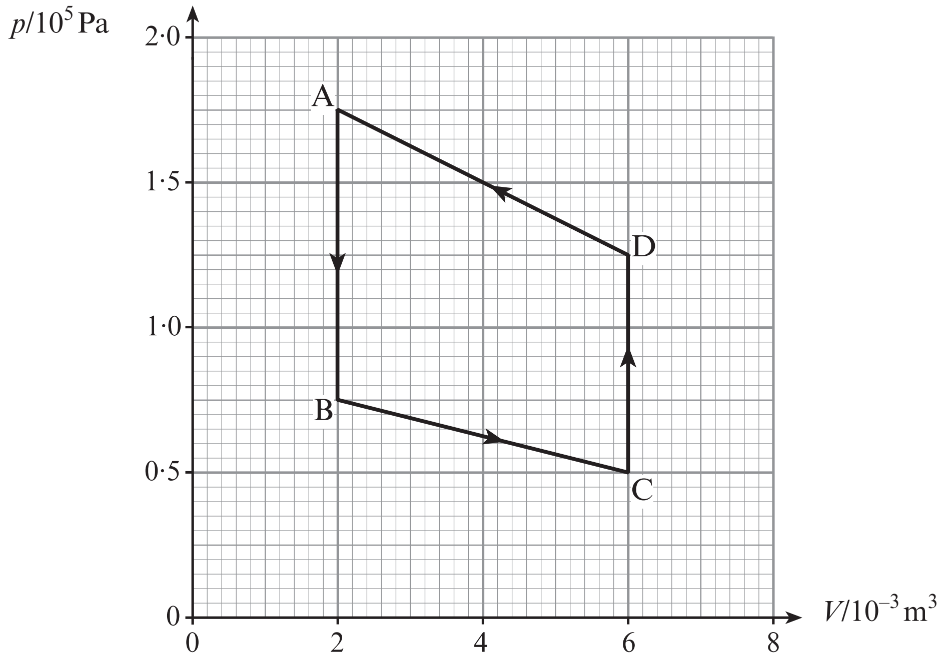
Question			Marking details	Marks Available
3	*(a)*		$pV = nRT$ (**subs**)(1) $n = \dfrac{60\times10^3\times0.05}{8.31\times278}$ (1) [=1.2986]	2
	(b)	(i)	**Either** $p = \frac{1}{3}\rho\overline{c^2}$ (1)* $\rho = \dfrac{m}{V}$ or $\dfrac{0.171}{0.05}$ (1) $c_{rms} = 229\ \text{m s}^{-1}$ (1) **or** $pV = \frac{1}{3}Nm\overline{c^2}$ (1) $v = 0.05\ \text{m}^3$ **and** $Nm = 0.171$ (1) $c_{rms} = 229\ \text{m s}^{-1}$ (1) * Mark lost for incorrect substitution (e.g. of ρ) unless final root taken.	3
		(ii)	Division of m by 1.3 (1) Molar mass =0.132 kg / 132 g ((**unit**)) (1)	2 **[7]**
4.	*(a)*		ΔU – <u>change</u> / <u>increase</u> in *internal energy* Q – *Heat* supplied <u>to the gas /system</u> W – *Work* <u>done by the gas / system</u> Marking – all *italic* terms (1); all <u>underlined</u> terms (1)	2
	(b)	(i)	$W = p\Delta V$ **or** area under graph (1) $= 60\ 000 \times 50 \times 10^{-3}$ $= 3\ 000$ J (1)	2
		(ii)	Use of ΔT or $U_2 - U_1$ (1) $\Delta U = 4\ 500$ J (1)	2
	(c)	(i)	0	1
		(ii)	Temperature decreases / gas cools / ΔU –ve (1) Heat flows out / Q –ve (1) [**not** 'decrease in heat']	2
	(d)	(i)	Returns to same temperature / point / p, V, T (1) [**or** internal energy depends only on T [accept p, V, T]]	1
		(ii)	attempt at closed area or AB – CD (1) [or by impl.] W [= 20 000 × 0.05] = 1000 J (1) Q = 1000 J (1)	3 **[13]**

Examiner only

2. A gas undergoes the cycle ABCDA as shown in the p-V graph below.



(a) Explain very briefly why no work is done during AB or CD. [1]

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(b) Calculate the work done by the gas during process DA. [3]

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(c) The first law of thermodynamics is usually written

$\Delta U = Q - W$

State the meaning of each term. [3]

ΔU ....

Q ....

W ....

(d) Calculate the heat flow out of the gas during the cycle ABCDA. [3]

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Examiner only

3. Describe an everyday circumstance where resonance occurs. Your example of resonance may be useful or it may be an example where resonance should be avoided. You should explain what is your oscillating system, what provides the driving force and what is the result of the resonance. A diagram may (or may not) assist your answer. [4]

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PH4 Mark scheme – January 2011

2.	*(a)*		$\Delta V = 0$ / no change in volume	1
	(b)		Work done = area under graph or by impl. [i.e. area calc attempt] (1) Work done [= [–]$1.5 \times 10^5 \times 4.0 \times 10^{-3}$]= [–] 600 J (1) Minus sign (1) [free-standing mark] [NB Any reasonable method of determining area, including counting squares ✓]	3
	(c)		ΔU: <u>change</u> [or <u>increase</u>] in <u>internal energy</u> of …(1) Q: <u>heat supplied</u> ["heat in" etc. – direction must be indicated] to ……(1) W: <u>work</u> done <u>by</u> …..(1) [NB: **not** "by or on"] [Subtract 1 mark if "gas" or "system" not mentioned at least once].	3
	(d)		Attempt at area inside the cycle or Area $_{BC}$ – Area $_{DA}$ (1) Area / W [= $0.675\times 10^5 \times 4.0 \times 10^{-3} - 600$] = – 350 J (1) $\therefore$ $Q = -350$ J (1) [NB final step must be explicit – leaving answer for W doesn't gain the final mark]	3 **[10]**

Question			Marking details	Marks Available
3			Sample answer: Microwave oven [although away from central resonance] (1). Driving force: the [e-m fields of the] microwaves (1) Oscillating System: rotation [accept vibration] of water molecules (1) Result: Increased [accept large amplitude] rotational k.e. (1) General scheme: 4 distinct points needed $\rightarrow 4 \times (1)$ Diagram / statement of application [e.g. bridge, car rattle…] ✓ Description of plausible oscillating driving force ✓ Description of plausible system ✓ Large amplitude because of same frequency [or graph showing resonance, with labelled axes]✓	4 **[4]**

Examiner only

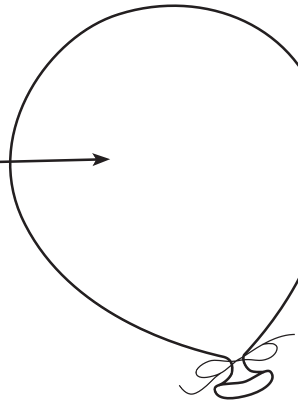
1. A toy balloon contains gas for which data are given.

pressure = 1.10×10^5 Pa

density = $1.25\,\text{kg}\,\text{m}^{-3}$

total mass of air (M) = 3.75 g

number of particles = 8.06×10^{22}



(a) Calculate the rms speed of the molecules inside the balloon. [2]

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(b) Show that the molar mass of the gas inside the balloon is approximately 28. [2]

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(c) (i) Calculate the momentum of a gas molecule of mass 4.65×10^{-26} kg travelling at a speed of $460\,\text{m}\,\text{s}^{-1}$. [2]

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(ii) Calculate the wavelength of a photon of light that has the same momentum as this gas molecule. [2]

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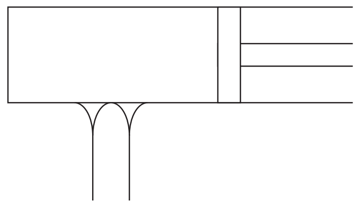
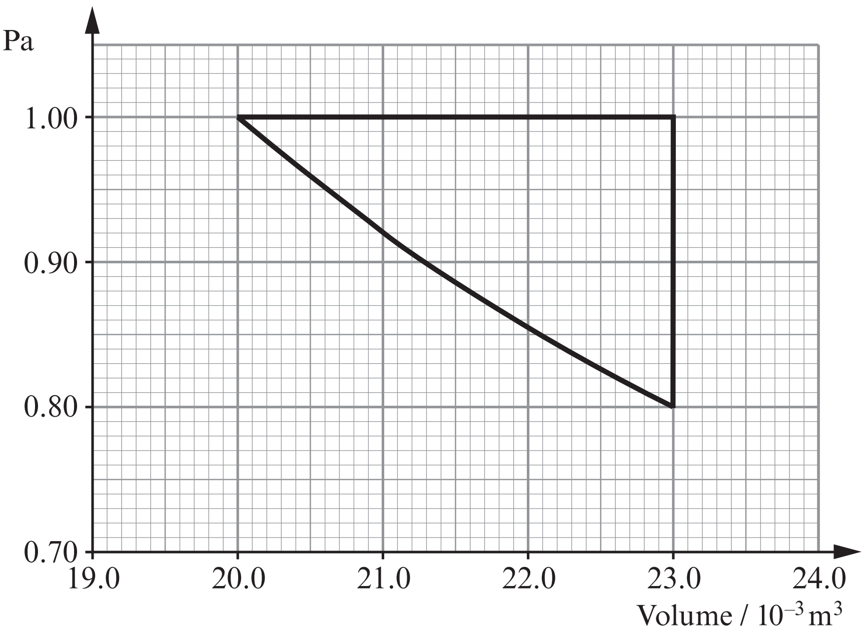
Turn over.

2. *(a)* (i) Gas inside a cylinder is heated using a Bunsen burner.



The gas expands at constant pressure.
Label the start of this expansion **A** and the end **B** on the *p*-*V* graph below. [1]



(ii) The gas is now cooled at constant volume from **B**.
Label the end point of this process **C**. [1]

(b) When the gas is at a pressure of 1.00×10^5 Pa and has a volume $20.0 \times 10^{-3}\,m^3$, its temperature is 323 K.

(i) Calculate the total number of moles of gas. [2]

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(ii) Calculate the total number of molecules of gas. [1]

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Examiner only

(iii) Calculate the temperatures of the gas at **B** and **C**. [2]

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(c) For **BC**, the gas was cooled by pouring 0.125 kg of cold water over the piston. The amount of heat that flowed out of the gas was 715 J. Calculate the increase in temperature of the cold water given that the specific heat capacity of water is $4200\,\mathrm{J\,kg^{-1}\,K^{-1}}$. [2]

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(d) Estimate the total work done by the gas for the whole cycle **ABCA**. [3]

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(e) Explain why your answer to *(d)* is also the heat flowing into the gas during the cycle **ABCA**. [2]

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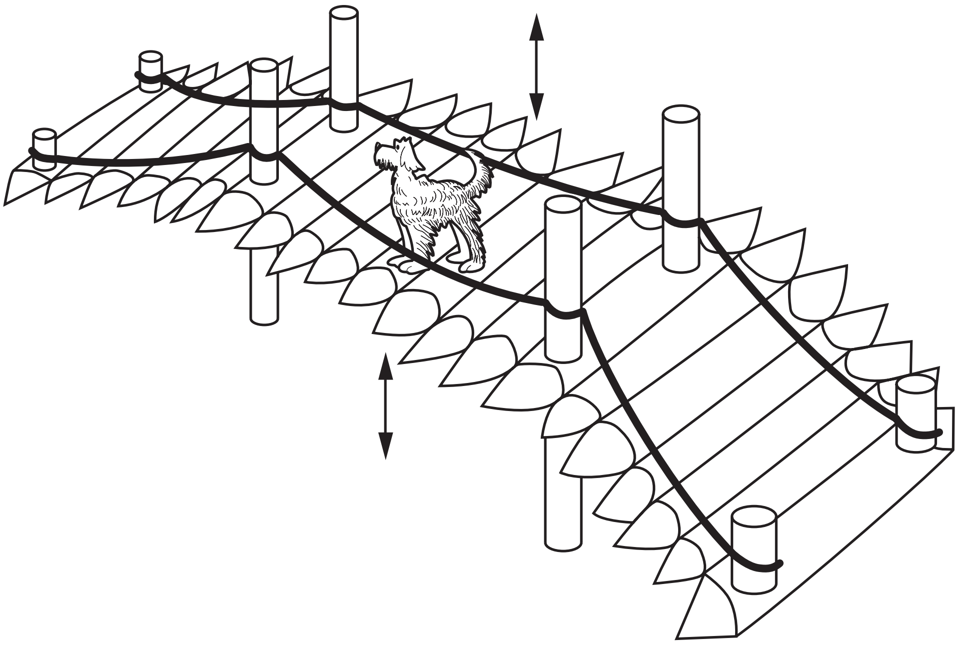
Examiner only

6. A poorly-designed bridge oscillates up and down at its natural period of 0.81 s.



(a) Calculate the natural frequency of oscillation. [2]

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(b) Show that the angular velocity of the oscillations is approximately 7.8 rad s^{-1}. [2]

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(c) When people walk across this bridge, oscillations of large amplitude occur. Explain the cause of the large-amplitude oscillations and the possible consequences. [3]

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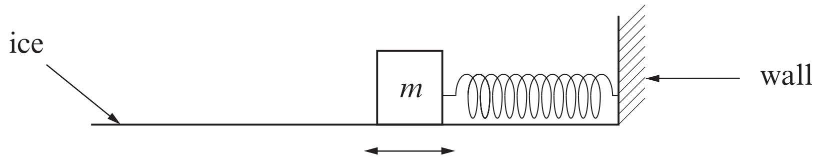
PH4

Question			Marking details	Marks Available
1	(a)		$p = \frac{1}{3}\rho\overline{c^2}$ rearranged e.g. $\overline{c^2} = \frac{3p}{\rho}$ (1) $c_{rms} = 514$ [m s^{-1}] (1)	2
	(b)	(i)	Mass of particle = $\frac{3.75}{8.06\times10^{22}}$ g (1) [4.63×10^{-26} kg] = 27.9u (1) [so molar mass = 27.9 [g mol^{-1}] [~ 28 g mol^{-1}] **Or:** Amount of gas = $\frac{8.06\times10^{22}}{6.02\times10^{23}}$ mol (1) [= 0.134 mol] So molar mass = $\frac{3.75\text{ g}}{0.134\text{ mol}}$ [=28 g mol^{-1}]	2
	(c)	(i)	$p = mv$ used , e.g. $p = 460m$ (1) $p = 2.14 \times 10^{-23}$ kg m s^{-1} / N s ((**UNIT mark**)) (1)	2
		(ii)	$\lambda = \frac{h}{p}$ (1)[manipulation: $p = \frac{h}{\lambda}$ by itself is not enough] [or by impl.] $\lambda = 3.1 \times 10^{-11}$[m] (1) Allow e.c.f.	2
			Question 1 total	**[8]**
2	(a)	(i)	(20.0, 1.00) labelled A and (23.0, 1.00) labelled B	1
		(ii)	(23.0, 0.80) labelled C	1
	(b)	(i)	$n = \frac{pV}{RT}$ (1) [manipulation – or by impl.] = 0.745 [mol] (1)	2
		(ii)	[$N = nN_A$ =] 4.5×10^{23} Allow e.c.f.	1
		(iii)	$T = \frac{pV}{nR}$ [or by impl.]; (or V/T = constant or P/T = constant) $T_B = 371$ [K] **and** $T_C = 297$ [K] (1) e.c.f.	2
	(c)		at least two values substituted into $E = mc\Delta\theta$ (1) $\Delta\theta = 1.36$ [K or °C] (1)	2
	(d)		Area under graph = work or by clear implication (1) detail, e.g. ½ × 0.21×10^5 × 3 × 10^{-3} (1) [square counting ok] 31.5 [J] or 30 [J] (ans) (1)	3
	(e)		$\Delta U = Q - W$ quoted or by clear implication or 1st law quoted (1); and $\Delta U = 0$ (1)	2
			Question 2 total	**[14]**

Question			Marking details	Marks Available
6	(a)		$f = \dfrac{1}{T}$ (1); f = 1.23 [Hz] (1)	2
	(b)		$\omega = 2\pi f$ or $\dfrac{2\pi}{T}$ (1) = 2π x 1.23 (allow e.c.f.) or 2π/0.81 = (7.76 rad s^{-1})	2
	(c)		natural frequency (period) close to walking frequency (period) (1) **resonance** occurs (1) which could break (or damage) bridge (1)	3
	(d)		A and ω subbed into $y = A \sin \omega t$ (1) $y = -$ 10.3cm (1) [N.B. y ~2.0 cm if calculators set to degrees - 1 mark only]	2
	(e)	(i)	$a = \omega^2 x$ or $\omega^2 A \sin \omega t$ (1) $\omega^2 x = 9.81$ m s^{-2} (1) x = 16.1 [cm] [16.3 if ω=7.76 rad s^{-1} used] (1)	3
		(ii)	Point indicated at ~ 0.12 s ecf (1) and 2nd point anywhere > 0.28 s (1)	2
			Question 6 Total	**[14]**

Examiner only

1. *(a)* A mass, m, is attached to a spring and oscillates horizontally with simple harmonic motion on the floor of an ice rink. Its frequency of oscillation is 0.625 Hz and the spring constant of the spring is $2\,640\,\mathrm{N\,m^{-1}}$.



(i) Show that the mass, m, is approximately 170 kg. [3]

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(ii) The maximum kinetic energy of the mass is 2.15 kJ. Calculate its maximum speed. [2]

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(iii) State the maximum potential energy stored in the spring and explain your reasoning. [2]

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(iv) Calculate the amplitude of oscillation. [2]

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Examiner only

(v) At time $t = 0$, the displacement of the mass is zero. Calculate the **acceleration** of the mass at time $t = 1.40$ s. [3]

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(b) Explain briefly, why pushing the mass every 1.60 s would result in large amplitude oscillations. [2]

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(c) Later, when the mass is released from its maximum displacement of 2.00 m an observer starts a stopwatch. After 5.0 s, the amplitude of oscillation has decreased to 1.40 m. Sketch a displacement-time graph of the damped oscillations on the grid below. [3]

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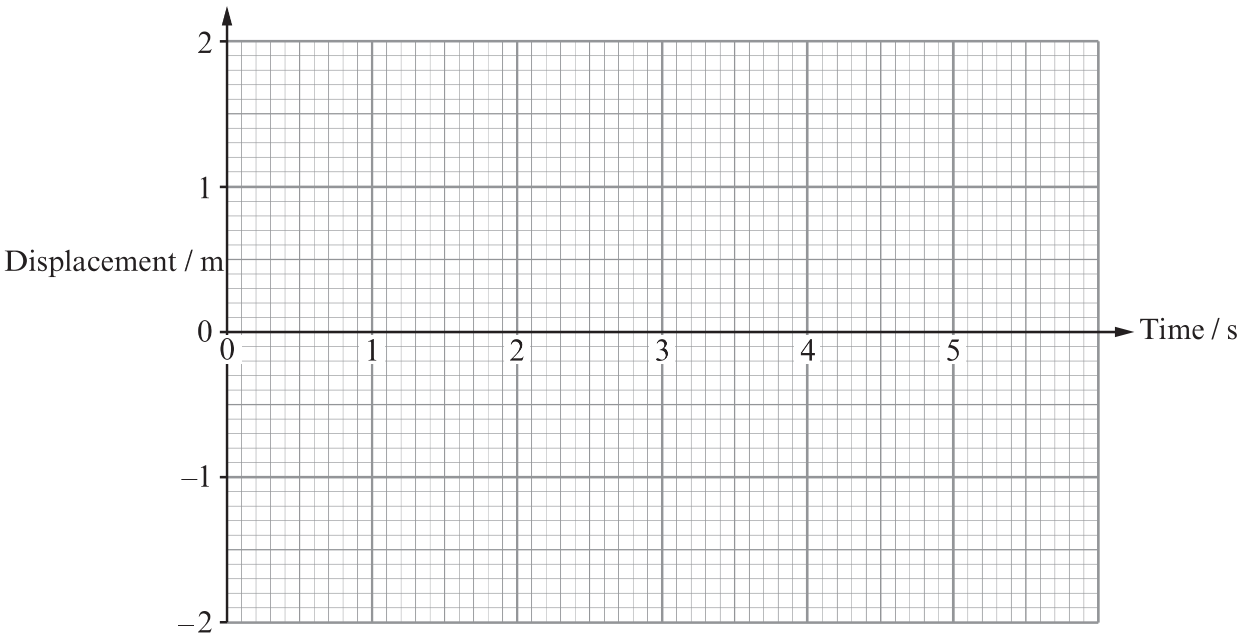
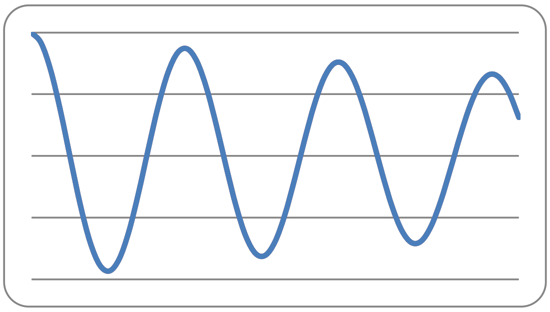


GCE Physics - PH4

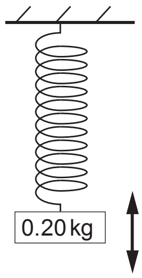
January 2013 - Markscheme

Question			Marking details	Marks Available
1	*(a)*	(i)	$T = \frac{1}{f} = 1.6$ **or** $\omega^2 = \frac{k}{m}$ (1) algebra i.e. $m = \frac{T^2 k}{4\pi^2}$ **or** $\omega = 2\pi f$ (1) $m = \frac{1.6^2 \times 2640}{4\pi^2}$ (1) = [171 kg]	[3]
		(ii)	$\frac{1}{2}mv^2 = 2150$ (1) $v = 5.01$ [m s^{-1}] (1) **ecf** on m	[2]
		(iii)	2.15 [kJ] (1) conservation of energy stated or implied / **all** KE transferred to PE (1) (accept energy cannot be created or destroyed)	[2]
		(iv)	$v = \omega A$ (1) or suitable alternative $A = 1.28$ [m] (1) **ecf**	[2]
		(v)	$x = \pm A \sin(2\pi f t)$ (1) For 1st mark ω must be substituted. $a = -\omega^2 x$ used **(1)** 13.9 [m s^{-2}] (1) **ecf**	[3]
	(b)		Resonance / maximum amplitude (1) since natural frequency / $\frac{1}{0.625} = 1.6$ (1)	[2]

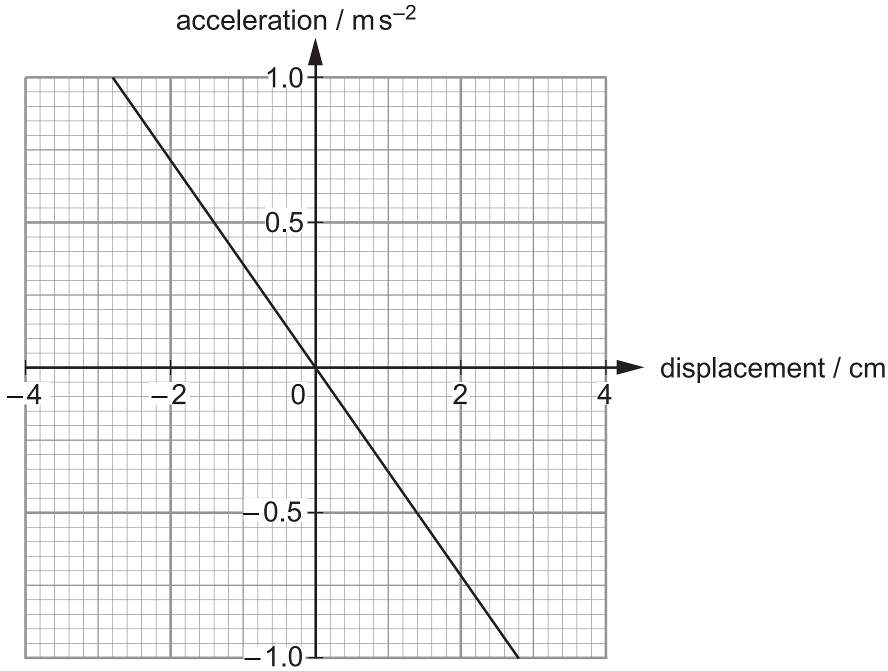
Question			Marking details	Marks Available
	(c)		Basic shape (decreasing to 1.4 m with a cos or –cos shape) (1) period = 1.6 s (accept 1.5 – 1.7 s) (1) period constant (1) 	[3]
			Question 1 total	**[17]**

Examiner only

3. A mass oscillates vertically on a spring as shown.



(a) The graph below shows the variation of acceleration with displacement of the mass on the spring.



(i) Explain how the graph verifies that the mass will perform simple harmonic motion. [2]

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(ii) Use the graph to show that the frequency of oscillation of the mass on the spring is approximately 1 Hz. [3]

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Examiner only

(iii) The amplitude of oscillation of the mass on the spring is 2.8 cm. Write down (or calculate) the maximum acceleration of the mass. [1]

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(iv) Calculate the maximum kinetic energy of the 0.20 kg mass. [3]

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(v) If the mass is moving upwards at its maximum speed when $t = 0$ s, calculate the first time that the mass moves upwards with a speed of $0.100\ \mathrm{m\,s^{-1}}$. [3]

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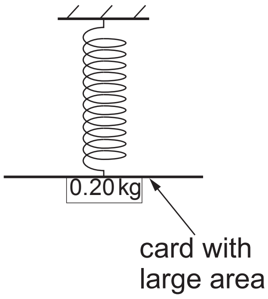
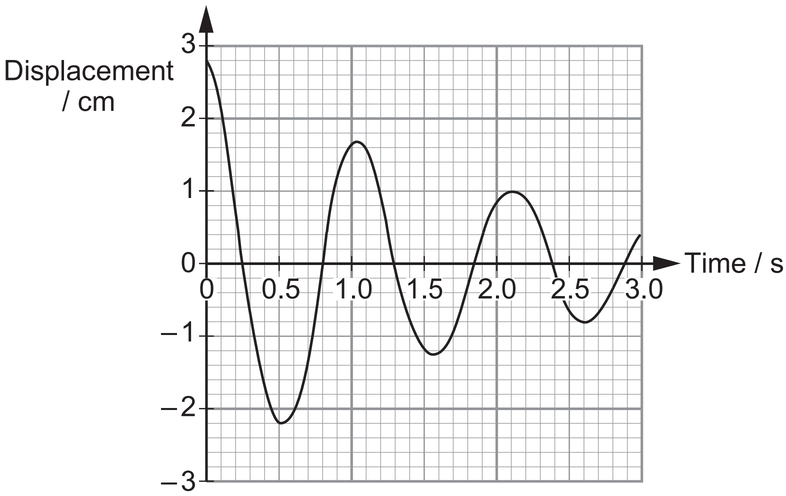
Examiner only

(b) When damping is introduced the following graph of displacement against time is obtained. Explain how the principle of conservation of energy applies during the cycles shown. [4]





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Question				Marking details	Marks Available
3	(a)	(i)		Graph is straight line through origin [hence proportional] (1) (accept acceleration is proportional to displacement) Negative gradient [hence direction ok] (1)	2
		(ii)		Gradient calculated correctly i.e. $\frac{1}{0.028}$ or 36 (or k calculated from $ma = kx$ i.e. 7.14 N m^{-1}) (1) Gradient = angular velocity squared i.e. method **explained** Or $f = \left(2\pi\sqrt{\frac{m}{k}}\right)^{-1}$ i.e. equation for T **and** $f = 1/T$(1) Answer = $\frac{5.98}{2\pi}$ = 0.95 [Hz] (1)	3
		(iii)		1 m s^{-2} read off graph Or 6^2 x 0.028 = 1 [m s^{-2}]etc.	1
		(iv)		Max speed = ωA or implied (= 0.167) (1) KE = $\frac{1}{2}mv^2$ or implied (1) Answer = 2.8 [mJ] (1) **ecf**	3
		(v)		$v = A\omega\cos\omega t$ used or $\varepsilon = 0$ stated (1) Rearrangement e.g. $\omega t = \cos^{-1}\frac{v}{A\omega}$ or implied (1) Correct answer = 0.156 [s] (1) **ecf**	3
	(b)			KE to PE **or** PE to KE (1) PE is both GPE and EPE (1) Energy gradually lost due to friction or air resistance or internal energy of spring/air etc. Not sound, not heat by itself - needs more e.g. lost as heat to the air ok (1) Detail of energy loss e.g. internal energy of air, KE of air particles	4
				Question 3 total	**[16]**

Examiner only

2. The air in a room of dimensions $6.0\,\text{m} \times 5.0\,\text{m}$ and height $3.0\,\text{m}$ is at atmospheric pressure, 1.01×10^5 Pa, and a temperature of 293 K.

(a) Write two assumptions of the kinetic theory of gases.

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(b) Calculate the number of air molecules in the room.

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.... [2]

(c) At some instant three of the molecules in the room have respectively speeds of $350\,\text{m s}^{-1}$, $420\,\text{m s}^{-1}$ and $550\,\text{m s}^{-1}$. Calculate the root-mean-square (r.m.s.) speed of these three molecules at this instant.

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.... [2]

(d) Show that the r.m.s. speed of all the molecules in the room is approximately $500\,\text{m s}^{-1}$. (Mean relative molecular mass of air = 29)

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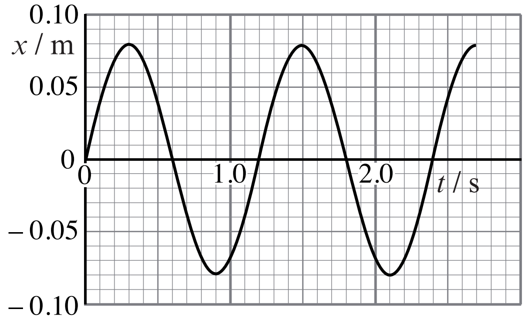
.... [4]

Question			Marking details	Marks Available
2.	*(a)*		Any 2 × (1) of: • forces between molecules negligible [or no forces…] / molecules travel in straight lines between collisions ✓ • volume [allow "size"] of molecules negligible / collision time small [cf time between collisions] ✓ • molecules behave like perfectly elastically / have elastic collisions ✓ • molecules exert forces [or pressure] on walls of container during collisions ✓ • gasses consist of a large number of particles / molecules in random motion	2
	(b)		amount of gas, $n = \left[\frac{pV}{RT} = \frac{1.01\times10^5\times(6\times5\times3)}{8.31\times293} = \right]$ 3730 mol (1) no. of molecules $N = nN_A$ = 3730 × 6.02 × 10^{23} = 2.2 × 10^{27} (1)	2
	(c)		$c_{rms} = \sqrt{\frac{350^2+420^2+550^2}{3}}$ (1) [or by impl.] = 448 m s^{-1} (1)	2
	(d)		Density ρ = (1) $\frac{M}{V} = \frac{3733\times\frac{29}{1000}(1)}{90}$ [= 1.203 kg m^{-3}]. Use of $p = \frac{1}{3}\rho\overline{c^2}$ (1). [c_{rms} = 502 m s^{-1}]. (1) (i.e. use of M/V (1); inserting ~3733 for n (1); relating M to Mr (1); use of $p = \frac{1}{3}\rho\overline{c^2}$ and substitution [or by impl.] (1))	4
	(e)	(i)	Time of travel ~ 0.01 – 0.02 s	1
		(ii)	No – time estimated is [far] too short (1) e.c.f from (i) Relay is much longer because of collisions between molecules [or equiv. eg takes time to diffuse / mean free path is very short] (1)	2
				[13]

Examiner only

2. A steel ball of mass 0.40 kg hangs by a spring from a fixed support. The ball is displaced vertically from its equilibrium position and then released. A graph of **upward** displacement *(x)* from the equilibrium position against time *(t)* is plotted from readings obtained using a video camera.



(a) (i) How can you tell that $t = 0$ is not the time when the ball was released? [1]

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(ii) Write down the values of

(I) the *amplitude* of the oscillations. [1]

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(II) the *periodic time*. [1]

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(b) Calculate the *stiffness, k* (the force per unit extension), of the spring. [2]

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(c) (i) Show that the maximum speed of the ball is approximately 0.4 ms^{-1}. [2]

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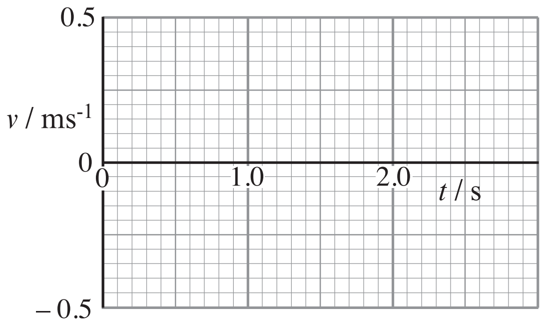
(ii) Sketch a graph of velocity *(v)* against time on the grid alongside. The maximum, minimum and zero values should be plotted carefully.



[2]

Examiner only

(d) (i) Calculate the changes in *kinetic energy* and *gravitational potential energy* of the ball which occur between t = 0.60 s and t = 0.90 s. State whether each is an increase or decrease.

(I) change in kinetic energy [2]

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(II) change in gravitational potential energy [1]

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(ii) Explain, without further calculation, how the *Principle of Conservation of Energy* applies over this interval. [1]

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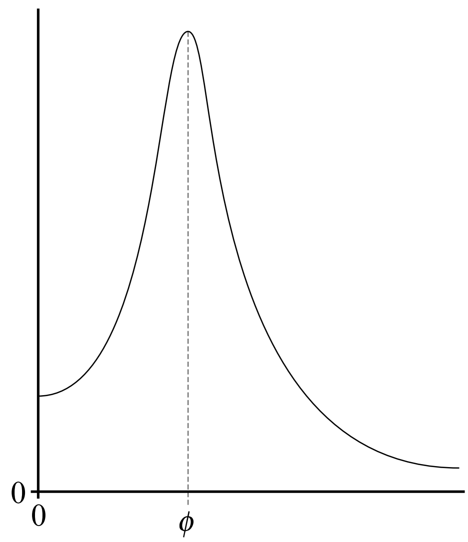
(e) The spring with its suspended steel ball is now hung from the pin of a vibration generator. This is connected to a signal generator so that the pin moves up and down. Using this apparatus, readings can be taken for a *resonance curve.* The curve is sketched alongside.



(i) Label the graph axes with the physical quantities plotted. [1]

(ii) Determine the expected value of ϕ, explaining your reasoning. [2]

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Turn over.

Examiner only

3. A cylinder fitted with a leak-proof piston contains 2.4×10^{-3} kg of argon gas at a pressure of 100 kPa. The volume of the gas is 1.5×10^{-3} m^3.

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

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(II) At any instant some of the molecules will have speeds much greater than the rms speed of all the molecules. How could they have acquired such speeds? [1]

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(III) Three of the molecules have speeds 935 ms^{-1}, 743 ms^{-1}, and 312 ms^{-1}. Calculate the rms speed of these three molecules. [3]

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(ii) There are 0.0600 moles of argon gas in the cylinder.

(I) Show that the temperature of the gas is approximately 300 K. [2]

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(II) Calculate the number of molecules of argon in the cylinder. [1]

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(III) Calculate the relative molecular mass of argon. [2]

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Question			Marking details	Marks Available
2.	*(a)*	(i)	Relevant comment, e.g. stem suggests not at equilibrium when released / graph shows equilibrium at t = 0 / graph contradicts stem	1
		(ii)	I. 0.08 m (1) II. 1.2 s (1)	1 1
	(b)		$k = \dfrac{4\pi^2 m}{T^2}$ (1) [correct transposition at any stage] $= 11\ \text{N m}^{-1}$ (1) ((**unit** including any SI equivalent))	2
	(c)	(i)	{$\omega = 5.24\ \text{rad s}^{-1}$} **or** {use of $v_{\text{max}} = \dfrac{2\pi A}{T}$ [or equiv]}(1) $v_{\text{max}} = 0.42\ \text{m s}^{-1}$ [accept $v_{\text{max}} = 0.080 \times 5.24$] + comment (1) [Full marks available for use of tangent → $T = 0.42 \pm 0.7\ \text{m s}^{-1}$]	2
		(ii)	Correct sequence of v values (i.e. correct phase) (1) t values correct, and reasonable curve plotted (1)	2
	(d)	(i)	I. – [or “decrease”] (1) 0.035 J [± 0.003 J] (1) II. – 0.31 J [±0.01 J] NB Correct sign required.	2 1
		(ii)	[0.35J of] elastic [potential] energy gained (1) [Accept: [more] energy stored in spring [at 0.9s]]	1
	(e)	(i)	ordinate labelled “amplitude” and abscissa labelled “frequency”	1
		(ii)	ϕ is [close to] the natural frequency [or by implication] (1) [NB **not** resonant frequency] 0.83 Hz (1) [e.c.f. from *(a)*(ii)(II)]	2
				16

Question			Marking details	Marks Available
3.	*(a)*	(i)	I. $\overline{c^2} = \frac{3p}{\rho}$ (1) [transposition at any stage] $= \frac{3 \times 100 \times 10^3 \times 1.5 \times 10^{-3}}{2.4 \times 10^{-3}}$ (1) [correct substitution or by implication] $\sqrt{\overline{c^2}} = 433\text{ m s}^{-1}$ (1) [Wrong attempts based on $pV = \frac{1}{3}Nm\overline{c^2}$ can score the last mark if $\sqrt{}$ correctly taken]	3
			II. collisions ["random process" not enough]	1
			III. $935^2 + 743^2 + 312^2$ [$= 1.52 \times 10^6$] (1) Division of sum by 3 even if $\frac{935 + 743 + 312}{3}$ [$= 663\text{ m s}^{-1}$] (1) $C_{\text{rms}} = 712\text{ m s}^{-1}$ (1) [no ecf]	3
		(ii)	I. $T = \frac{pV}{nR}$ (1) [transposition at any stage] $T = 301$ K **or** $\{\frac{100 \times 10^3 \times 1.5 \times 10^{-3}}{0.050 \times 8.31} = 300$ K or 301 K$\}$ (1)	2
			II. $N = 3.6 \times 10^{22}$	1
			III. rmm $= \frac{2.4}{0.0600}$ (1) [award mark even if 2.4× used] = 40 (1) [NB no unit penalty]	2
	(b)	(i)	Attempt to find area under AB / use of $p\Delta V$ [or by implication] (1) 100 J (1)	2
		(ii)	Either $T_B = 500$ K (1) [or by impl.] $U_B = 374$ J **or** $U_A = 224$ J (1) [or by impl.] $\Delta U = 150$ J (1) Or $U = \frac{3}{2}pV$ (1) [or by impl] $\Delta U = \frac{3}{2}p\Delta U$ (1)[or by impl.] = 150 J (1)	3
		(iii)	250 J [e.c.f.]	1
		(iv)	[U falls by 150 J and because the volume doesn't change] no work involved / $Q = \Delta U$ (1) 150 J (1) [ecf on answer to (ii)]	2
				20

Examiner only

5. A canister of volume 0.025 m^3 contains helium gas at a pressure of 3.04×10^5 Pa and a temperature of 280 K. (Relative molecular mass of helium = 4.0)

(a) Calculate:

(i) the number of moles of the gas in the canister; [1]

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(ii) the number of helium molecules in the canister; [1]

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(iii) the density of the gas; [2]

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(iv) the rms speed of the helium molecules. [2]

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Examiner only

(b) The product of the pressure and volume of an ideal gas may be expressed as

$$pV = nRT.$$

The product may also be written in terms of the mean square speed of the molecules as

$$pV = \frac{1}{3}Nm\overline{c^2}.$$

(i) Derive in clear steps a formula that shows how the internal energy of the ideal gas depends on the temperature of the gas. [4]

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(ii) Calculate the internal energy of the helium gas in the canister. [1]

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Question			Marking details	Marks Available
5	*(a)*	(i)	$PV = n\,RT$ $n = \frac{PV}{RT} = \frac{(3.04 \times 10^5)(0.025)}{(8.31)(280)} = 3.27[\text{mol}]$	1
		(ii)	$N = n\,N_A = (3.27)\,(6.02\text{x}10^{23}) = 1.97\text{x}10^{24}$ **allow ecf from (i)**	1
		(iii)	$\rho = \frac{(m_r \text{ x } 10^{-3})n}{V} = \frac{(4\text{x}10^{-3})(3.27)}{0.025} = 0.52[\text{ kg m}^{-3}]$ (1) formula with m_r (1)	2
		(iv)	$P = \frac{1}{3}\rho\overline{c^2}$ $\sqrt{\overline{c^2}} = \sqrt{\frac{3P}{\rho}} = \sqrt{\frac{3(3.04x10^5)}{0.52}} = 1324[ms^{-1}]$ (1) **allow ecf from (iii)** Rearrange equation (1)	2
	(b)	(i)	(Combining of the two given equations to give) $\frac{1}{3}N m\overline{c^2} = nRT$ (1) KE of gas (i.e. of the N molecules) = $\frac{1}{2}N m\overline{c^2}$ [= number of atoms x $\frac{1}{2}m\overline{c^2}$] (1) (can award for K.E. of one molecule i.e. K.E. = $\frac{1}{2}m\overline{c^2}$ only if it is clearly noted that it is for one molecule) $\therefore$ KE of gas [$\frac{1}{2}N m\overline{c^2}$] = $\frac{3}{2}nRT$ manipulation mark (1) Internal energy of gas (U) = KE + PE and PE = 0 (for ideal gas) (1) [or internal energy is only the KE] (so $U = \frac{3}{2}n\,RT$)	4
		(ii)	$U = \frac{3}{2}n\,RT = \frac{3}{2}(3.27)\,(8.31)\,(280) = 11\,413$ [J]	1
			Question 5 Total	**[11]**

Examiner only

2. *(a)* A helium weather balloon is to be released.

volume = $0.113\,\text{m}^3$
temperature = $293\,\text{K}$
pressure = $1.02 \times 10^5\,\text{Pa}$

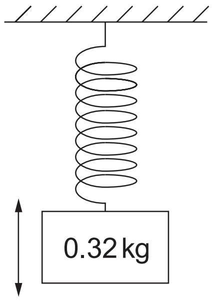
(i) Show that the density of the helium in the balloon is approximately $0.17\,\text{kg}\,\text{m}^{-3}$. (The molar mass of helium is $4.00 \times 10^{-3}\,\text{kg}\,\text{mol}^{-1}$.) [3]

(ii) Calculate the rms speed of helium molecules in the balloon. [2]

(b) The balloon is released and rises to a height where the pressure inside it decreases to $4.5 \times 10^4\,\text{Pa}$ and its volume increases to $0.212\,\text{m}^3$. Calculate the new rms speed of the helium molecules in the balloon (assume no helium molecules have escaped). [3]

Examiner only

4. A mass of 0.32 kg oscillates with simple harmonic motion vertically on a spring with a frequency of 3.47 Hz.



(a) Calculate the spring constant of the spring. [3]

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(b) Show that the angular velocity, ω, of the oscillations is 21.8 rad s^{-1}. [1]

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(c) The amplitude of oscillation of the spring is 8.5 cm. Calculate:

(i) the maximum kinetic energy of the mass; [3]

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Examiner only

(ii) the maximum resultant force acting on the mass. [2]

(d) The displacement of the mass is given by the equation $x = A\sin(\omega t + \varepsilon)$. Calculate a valid value for ε given that the displacement of the mass is –1.4 cm at time t = 0.100 s. [3]

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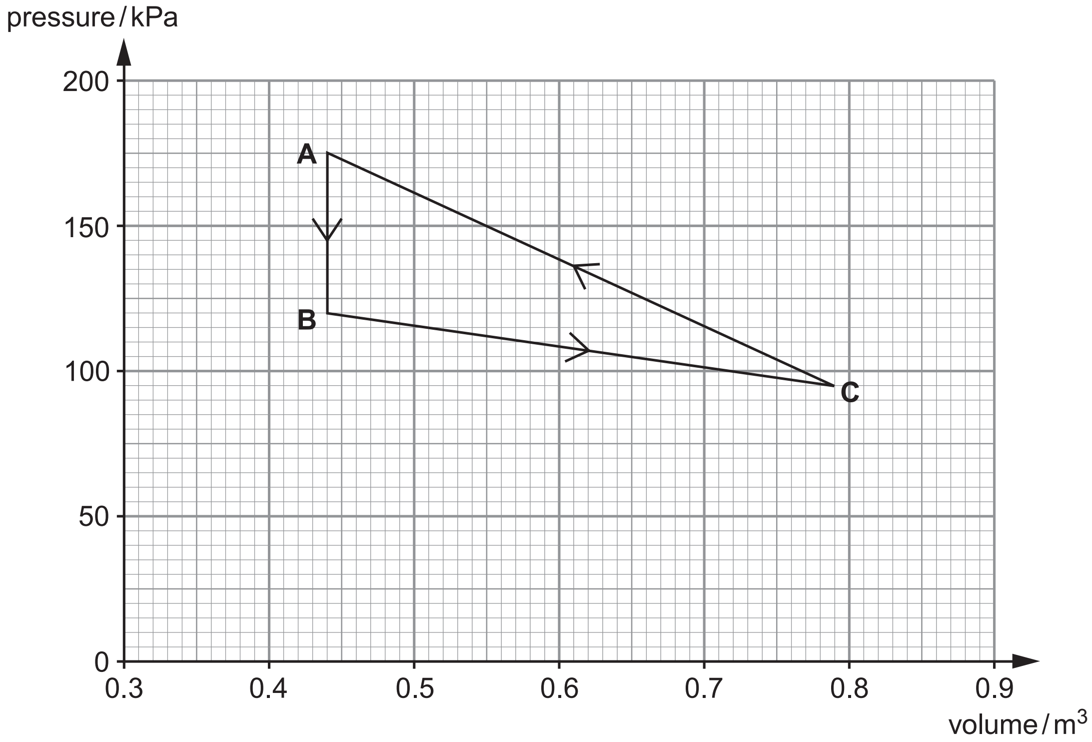
Examiner only

8. A sample of an ideal monatomic gas is taken through the closed cycle **ABCA** as shown.



(a) There are **28.9 mol** of gas. The temperatures of points **A** and **B** are 321 K and 220 K respectively.

(i) Show that the temperature of **C** is 313 K. [2]

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(ii) Calculate the change in internal energy, ΔU, for **AB**. [2]

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Examiner only

(b) Determine the work done **by** the gas, W, for:

(i) **AB**; [1]

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(ii) **CA**. [2]

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(c) For **each** of the processes **AB**, **BC**, **CA** and the whole cycle **ABCA**, write the values of W (the work done by the gas), ΔU (the change in internal energy of the gas) and Q (the heat supplied to the gas). The numbers in bold have been added to save time with repeated calculations. [4]

	Process			
	AB	**BC**	**CA**	**ABCA**
W		**37.6 kJ**		
ΔU		**33.5 kJ**	**2.9 kJ**	
Q				

Space for calculations:

END OF PAPER

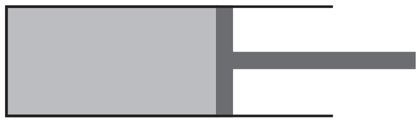
Question			Marking details	Marks Available
2	*(a)*	(i)	(Number of moles) n = 4.73 (1) Mass = 4 × 4.73 **or** 0.004 × 4.73 (**or** implied) (1) Density = 0.004 × 4.73 / 0.113 [= 0.167] (1)	3
		(ii)	Either $p = {}^1/_3\,\rho\overline{c^2}$ used **or** equivalent e.g. ${}^3/_2\,nRT = {}^1/_2\,M\overline{c^2}$ (1) 1 350 [m s^{-1}] (1)	2
	(b)		Density = 0.004 × 4.73 / 0.212 **or** $T = \frac{45000\times0.212}{4.73\times8.31}$ **ecf** (1) $p = {}^1/_3\,\rho\overline{c^2}$ used **or** ${}^3/_2\,nRT = {}^1/_2\,M\overline{c^2}$ used **or** equivalent (1) Answer = 1 230 [m s^{-1}] (1)	3
			Question 2 Total	**[8]**
3	*(a)*		Substitution into $v = \sqrt{\frac{GM}{r}}$ (1) Answer = 158 000 [m s^{-1}] (1)	2
	(b)		Measured velocity is greater (1) Which implies that the mass is greater (1) Suggests the existence of dark matter (1)	3
			Question 3 Total	**[5]**

Question			Marking details	Marks Available
4	*(a)*		Mass substituted into $T = 2\pi\sqrt{\frac{m}{k}}$ (1)	3
			$T = \frac{1}{f}$ used **or** implied (1)	
			Answer = 152 N m^{-1} **UNIT mark** (1)	
	(b)		3.47 × 2π [= 21.803]	1
	(c)	(i)	$v = \omega A$ [= 1.853] **or** max PE = max KE (1)	3
			KE = $^1/_2 mv^2$ used **or** = ½ kx^2 (1)	
			Answer = 0.55 [J] (1)	
		(ii)	Acceleration = $\omega^2 A$ **or** $F = kA$ Accept $F = kA - mg$ (1)	2
			Answer = 12.9 [N] (1)	
	(d)		Substitution of values e.g. $-1.4 = 8.5\sin(21.8 \times 0.1 + \varepsilon)$ (1)	3
			$\sin^{-1}\left(^{-1.4}/_{8.5}\right) = -0.165$ (1)	
			$\varepsilon = -2.35$ **or** equivalent in degree (-135°) **or** other quadrant (-5.16) **ecf** on minus sign (1)	
			Question 4 total	**[12]**

Question			Marking details	Marks Available
8	*(a)*	(i)	$T = \frac{pV}{nR}$ seen **or** equivalent **or** implied (1) $T = \frac{95000 \times 0.79}{28.9 \times 8.31}$ $(= 312.5\text{ K})$ (1)	2
		(ii)	$U = \frac{3}{2}nRT$ used **or** 3/2 pV (1) AB = -36 400[J] (1)	2
	(b)	(i)	0	1
		(ii)	Valid method either stated **or** clearly implied (1) Accept area under the graph Answer = - 47 250 [J] (1)	2
	(c)		<table><tr><td></td><td>AB</td><td>BC</td><td>CA</td><td>ABCA</td></tr><tr><td>W</td><td>0</td><td>37.6 kJ</td><td>-47.3 kJ</td><td>-9.7 kJ</td></tr><tr><td>ΔU</td><td>-36.4 kJ</td><td>33.5 kJ</td><td>2.9 kJ</td><td>0</td></tr><tr><td>Q</td><td>-36.4 kJ</td><td>71.1 kJ</td><td>-44.4 kJ</td><td>-9.7 kJ</td></tr><tr><td></td><td>✓</td><td>✓</td><td>✓</td><td>✓</td></tr><tr><td></td><td>**ecf** on ΔU</td><td>**no ecf**</td><td>**ecf** on W</td><td>**ecf** on all if $\Delta U \approx 0$ but must make sense</td></tr></table>	4
			Question 8 Total	**[11]**

Examiner only

3. Helium gas is contained in a closed cylinder with a leak-proof moveable piston at one end. Initially the volume is $1.2 \times 10^{-3}\,\text{m}^3$, the pressure is 3.0×10^5 Pa and the temperature is 275 K. (Relative molecular mass of helium = 4.0.)



(a) (i) Calculate the mass of the gas in the cylinder. [2]

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(ii) Calculate the rms speed of the molecules. [2]

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(b) The volume of the gas is increased to $1.8 \times 10^{-3}\,\text{m}^3$ at constant pressure. Calculate:

(i) the work done by the gas; [2]

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Examiner only

(ii) the heat supplied to the gas. [3]

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Question			Marking details	Marks Available
3	*(a)*	(i)	$pV = nRT$ $n = \frac{pV}{RT} = \frac{(3\times10^5)(1.2\times10^{-3})}{(8.31)(275)} = 0.1575$ mol (1) $\text{mass}, m_n = n \times M_r \times 10^{-3} = (0.1575)(4 \times 10^{-3})$ $= 6.30 \times 10^{-4}$ kg or 0.63 g (1) **unit mark**	2
		(ii)	$\text{density } \rho = \frac{m_n}{V} = \frac{6.30\times10^{-4}}{1.2\times10^{-3}} = 0.525$ kg m^{-3} (1) $p = \frac{1}{3}\rho\overline{c^2}$ rms $\sqrt{\overline{c^2}} = \sqrt{\frac{3p}{\rho}} = \sqrt{\frac{3(3\times10^5)}{(0.525)}} = 1\,309$ [m s^{-1}] (1) Allow 1 mark for 41.4 [m s^{-1}] and allow **ecf** from (i). [Alternatively $\frac{1}{2}m\overline{c^2} = \frac{3}{2}kT$ where $m = \frac{M_r\times10^{-3}}{N_A} = \frac{4\times10^{-3}}{6.02\times10^{23}}$ (1) $\sqrt{\overline{c^2}} = \sqrt{\frac{3kT}{m}} = \sqrt{\frac{3(1.38\times10^{-23})(275)(6.02\times10^{23})}{(4\times10^{-3})}} = 1\,309$ [m s^{-1}] (1)]	2
	(b)	(i)	Increase in volume $\Delta V = (1.8 - 1.2) \times 10^{-3} = 6 \times 10^{-4}$ m^3 (1) Work done by gas $= p\,\Delta V = (3 \times 10^5)(6 \times 10^{-4}) = 180$ [J] (1)	2
		(ii)	Final temperature $T_f = \frac{p\,V_f}{n\,R} = \frac{(3\times10^5)(1.8\times10^{-3})}{(0.1575)(8.31)} = 412.584$ K (1) Increase in internal energy of gas $\Delta U = \frac{3}{2}nR\,\Delta T = \frac{3}{2}(0.1575)(8.31)(412.584 - 275.0) = 270.110$ J (1) Heat flowing into gas $Q = \Delta U + W = 270.110 + 180 = 450$ [J] (1) Allow **ecf** from part (i)	3
			Question 3 Total	**[9]**