4(a)	<u>number</u> of oscillations per unit time	**B1**

4(b)(i)	kinetic energy (of object) reaches maximum / minimum / zero twice in a cycle	**A1**

4(b)(ii)	$\omega = 2\pi / T$ $= 2\pi / 0.80$ **or** $a_0 = \omega^2 x_0$ $\omega = \sqrt{(1.0 / 0.016)}$	**C1**
	$\omega = 7.9\ \text{rad s}^{-1}$	**A1**

4(b)(iii)	*Any three points from:* • oscillations are simple harmonic • <u>amplitude</u> = 0.016 m • maximum speed = 0.13 m s^{-1} • total energy of oscillations = 7.0×10^{-4} J • mass of object = 0.087 kg • maximum momentum = 0.011 kg m s^{-1} **or** 0.011 N s	**B3**

4(b)(iv)	*Any two points from:* • kinetic energy is a maximum at zero displacement **or** kinetic energy is zero at maximum displacement • potential energy is zero at zero displacement **or** potential energy is a maximum at maximum displacement • kinetic energy is maximum when the potential energy is zero **or** potential energy is a maximum when the kinetic energy is zero	**B2**
	kinetic energy + potential energy is constant	**B1**

Question 4

(a) Some candidates did not make the ratio number of oscillations *per* unit time clear or specified ‘per second’, so did not gain credit.

(b) (i) Many candidates did not explicitly reference the graph in Fig. 4.2 or kinetic energy, and so their attempts at explanations did not answer the question that had been asked.

(ii) Most candidates gained full credit.

(iii) A significant number of candidates identified the features in Fig. 4.1 but did not state that the oscillations were simple harmonic as a conclusion. Some candidates did not pay enough attention to the wording of the question and gave conclusions regarding period, frequency or angular frequency. Direct readings from the graphs such as maximum displacement, maximum acceleration and maximum kinetic energy were considered to be readings rather than drawn conclusions and were ignored. Many otherwise correct numerical answers had insufficient significant figures to gain credit.

(iv) Incorrect or inaccurate terminology was frequently used such as ‘at maximum amplitude’ or ‘at amplitude’ (for ‘at maximum displacement’) and ‘minimum’ kinetic energy or potential energy (for ‘zero’ kinetic energy or potential energy). Only the strongest candidates mentioned that kinetic energy + potential energy is constant.

5(a)(i)	straight line through the origin shows that *a* is proportional to *x*	**B1**
	negative gradient shows that *a* is always in the opposite direction to *x*	**B1**

5(a)(ii)	$a_0 = \omega^2 x_0$	**C1**
	$\omega = 2\pi / T$	**C1**
	$T = 2\pi \sqrt{(x_0 / a_0)}$ $= 2\pi \sqrt{(1.2 / 13)}$ $= 1.9$ s	**A1**

5(b)(i)	loss of energy of oscillations	**B1**
	due to <u>resistive</u> force(s)	**B1**

5(b)(ii)	line starting from $x = \pm 1.2$ cm at $t = 0$	**B1**
	line starting from non-zero value of *x* from $t = 0$ to $t = 2T$ that is entirely either above or below the *t*-axis	**B1**
	curve from $t = 0$ starting from non-zero *x* value, with both magnitude of *x* value and magnitude of gradient continuously decreasing	**B1**

Question 5

(a) (i) Many candidates gave a statement of the characteristic properties of simple harmonic motion without answering the question that asked how the graph demonstrates these properties.

(ii) This question was generally well answered, with full credit awarded to many candidates.

(b) (i) The meaning of damping was generally well known.

(ii) Many candidates began their graphs at the correct starting point, but many candidates drew curves for light damping rather than heavy damping.

1(a)	velocity and acceleration both have constant magnitude	**B1**
	velocity is (always) perpendicular to acceleration	**B1**

1(b)(i)	$v = R\omega$	**A1**

1(b)(ii)	$a = R\omega^2$ **or** $a = v^2 / R$	**C1**
	$a = v\omega$	**A1**

1(c)(i)	$x = R \sin \theta$	**A1**

1(c)(ii)	$\theta = \omega t$	**A1**

1(c)(iii)	clear substitution of $\theta = \omega t$ into $x = R \sin \theta$ leading to $x = R \sin \omega t$	**A1**

1(c)(iv)	equation is of the form $x = x_0 \sin \omega t$ (so simple harmonic motion)	**B1**

1(d)(i)	amplitude = 0.46 / 2 = 0.23 m	**A1**

1(d)(ii)	$\omega = 2\pi / T$	**C1**
	period $= 2\pi / 1.9$ $= 3.3$ s	**A1**

1(d)(iii)	$a_0 = \omega^2 x_0$	**C1**
	$= 1.9^2 \times 0.23$ $= 0.83$ m s^{-2}	**A1**

1(e)	shadow on screen, labelled A, above left-hand edge of the circular path	**B1**

Question 1

(a) Most candidates appreciated that velocity and acceleration were always perpendicular to each other in circular motion. A smaller number of candidates appreciated that the magnitude of the velocity (speed) was constant. It was rarely written that the magnitude of the acceleration was also constant.

(b) **(i)** This question was generally answered correctly.

(ii) Most candidates understood the relationship between acceleration and either angular or linear velocity. Some candidates did not identify that the question required a relationship to be given that included all three of those quantities.

(c) **(i)** Most candidates recognised that a sine term needed to be used in the expression.

(ii) This question was generally answered correctly.

(iii) This 'show that' question required candidates to include both equations from the two earlier parts of **(c)** before they made the substitution to match the given answer.

(iv) Many candidates ignored the requirement to refer to the given equation in **(c)(iii)**. Instead, correct relationships were often given between acceleration and displacement. Such answers were not able to gain credit as they did not answer the question that was asked.

(d) **(i)** This question was generally answered correctly, with most candidates understanding what is meant by amplitude.

(ii) Most candidates knew the relationship between angular frequency/velocity and period.

(iii) Successful responses made clear that the acceleration and displacement were the maximum values, by the inclusion of a subscript (a_0, x_0) in the equation used.

(e) This question considered the movement of the shadow on the screen. Only the strongest candidates appreciated that drawing the shadow as a whole gave a greater opportunity to correctly identify the position of maximum positive acceleration. A significant minority of candidates did not follow the instruction in the question to label the shadow with the letter 'A'. Stronger candidates appreciated that the maximum positive acceleration would occur at the extreme left-hand edge of the movement of the shadow.

4(a)	(motion in which) acceleration is (directly) proportional to displacement	**B1**
	(motion in which) acceleration is (always) in the opposite <u>direction</u> to displacement **or** acceleration is (always) directed towards a fixed point	**B1**

4(b)(i)	t_1 **and** t_5 **or** t_3 **and** t_7	**B1**

4(b)(ii)	$f = 1 / T$	**C1**
	period = 2.2 / 1.25 f = 1.25 / 2.2 = 0.57 Hz	**A1**

4(c)	$v_0 = \omega x_0$ **and** $\omega = 2\pi f$	**C1**
	$0.080 = 2\pi \times 0.57 \times x_0$	**C1**
	x_0 = 0.022 m	**A1**

Question 4

(a) The proportionality between acceleration and displacement was well understood, but the opposite direction of the two quantities was less clearly explained by some candidates. Candidates should ensure that they explain each term used if they quote an equation as part of their answer to this type of question.

(b) (i) This question tested the candidates' ability to match the velocity–time graph to the actual movement of the sphere, both in terms of speed and direction. Key to a producing a successful answer to this question was an appreciation of the direction of travel of the sphere during its oscillations.

(ii) Weaker candidates often confused the terms frequency and angular frequency.

(c) Where the starting equation of $\omega = v_0 / x_0$ was used, the identification of maxima for v and x using subscripts was not always made. A minority of candidates took the alternative (longer) route of using a tangent drawn on Fig. 4.2 to calculate the maximum acceleration and hence the amplitude. However, for most of those candidates, this graphical method introduced too great a degree of inaccuracy for full credit.

7(a)(i)	loss of energy (of oscillations)	**B1**
	due to resistive forces	**B1**

7(a)(ii)	amplitude (of oscillations) decreases gradually **or** oscillations continue (for several periods)	**B1**

7(a)(iii)	cutting of (magnetic) flux causes induced e.m.f. (in coil) **or** induced e.m.f. causes current (in resistor / circuit)	**B1**
	current causes dissipation of thermal energy in resistor **or** current in resistor causes dissipation of thermal energy	**B1**
	thermal energy comes from energy of oscillations	**B1**

7(b)	(for any given e.m.f.) current is lower so thermal energy dissipated at a lower rate **or** (for any given e.m.f.) current is lower so the resistive force is lower	**B1**
	oscillations are less damped **or** *s*maller decrease in amplitude of oscillations (in each period) **or** oscillations continue for longer	**B1**

Question 7

(a) (i) Stronger candidates identified both the change to the oscillations and the cause of that change. Weaker candidates confused the resistive force on the bar magnet with the resistance in the circuit.

(ii) The words ‘oscillation’, ‘displacement’, ‘amplitude’, ‘time’ and ‘period’ were often confused with each other by weaker candidates when describing the gradual reduction in amplitude over time. ‘Maximum amplitude’ was also an incorrect phrase seen.

(iii) This was one of the more difficult questions on the paper. Candidates were expressly required to focus on conservation of energy, and needed to link two parts of the process in their description, such as magnetic flux change and induced e.m.f., or current and thermal energy dissipation in the resistor. Only the strongest candidates were able to do so, with many candidates focusing instead on the impact of Lenz’s law and opposing forces. Whilst many candidates described a change of magnetic flux inducing an e.m.f., there was significant confusion over the process.

(b) Most candidates understood the effect of the increase in resistance, and correctly described the reduction in damping or the increase in the number of oscillations. Few candidates identified the lower thermal energy dissipation or lower resistive force caused by the reduction in the current.

5(a)	(motion in which) acceleration is (directly) proportional to displacement	**B1**
	(motion in which) acceleration is (always) in the opposite <u>direction</u> to displacement **or** acceleration is (always) directed towards a fixed point	**B1**

5(b)(i)	period $= 2\pi / 16$ $= 0.39\text{ s}$	**A1**

5(b)(ii)	$v_0 = \omega x_0$ **or** $v_0 = \omega\sqrt{\left(x_0^{\,2} - 0^2\right)}$	**C1**
	$x_0 = 0.56 / 16$ $= 0.035\text{ m}$	**A1**

5(b)(iii)	$v = \pm 16\ \sqrt{(0.0352 - x^2)}$	**A1**

5(b)(iv)	closed loop surrounding the origin	**B1**
	loop crosses $v = 0$ at maximum values of x at $x = \pm\ 3.5\text{ cm}$	**B1**
	loop crosses $x = 0$ at maximum values of v at $v = \pm\ 0.56\text{ m s}^{-1}$	**B1**

Question 5

(a) The definition of simple harmonic motion was generally well known.

(b) (i) This question was generally well answered, with most candidates realising that the angular frequency was 16 rad s^{-1} and using that correctly with $T = 2\pi / \omega$. A significant minority of weaker candidates had difficulty with the arithmetic and gave a two significant figure answer of 0.40 s.

(ii) Weaker candidates found this a more difficult question and could not determine the relationship between maximum velocity and maximum displacement. Stronger candidates were generally successful in getting to the correct answer.

(iii) A significant minority of candidates did not realise that this question required more than simply reproducing the general equation for velocity in terms of displacement from the formula sheet. The instruction that v is in m s^{-1} and x is in m made clear that numerical values of ω and x_0 needed to be substituted into this equation. Some candidates gave trigonometric expressions in attempting to give the variation of v with time, and others attempted to calculate a numerical answer. Many more able candidates did successfully substitute the appropriate values into the general equation but omitted the important $\pm$ symbol.

(iv) This question was generally well answered, with most candidates able to draw an oval-shaped loop passing within tolerance through the correct crossing points of the axes. Examiners allowed error-carried-forward from **(b)(ii)** for the crossing points of the x-axis, provided the candidate's value for x_0 lay within the range of the axis. A minority of weaker candidates attempted to sketch the variation of acceleration with displacement or the variation of velocity with time, but most candidates realised the correct shape for the variation of velocity with displacement.

5(a)(i)	amplitude = 0.60 m	**A1**

5(a)(ii)	oscillations are simple harmonic	**B1**

5(b)	*Any three points from:* • mean / equilibrium position is at h = 1.4 m • total energy of oscillations = 9.0 J • angular frequency of oscillations = 1.2 rad s^{-1} **or** period of oscillations = 5.1 s **or** frequency of oscillation = 0.19 Hz • maximum speed of block = 0.73 m s^{-1} • mass of block = 33 kg	**B3**

5(c)	U-shaped curve resting on h axis (with minimum at E_P = 0)	**B1**
	curve from h = 0.8 m to h = 2.0 m, with minimum E_P shown at h = 1.4 m	**B1**
	both end-points of curve shown at E_P = 9.0 J	**B1**

Question 5

(a) (i) Most candidates gave the correct answer.

(ii) Most candidates gave the correct answer.

(b) Despite the question being clear that quantitative conclusions were required, many candidates gave qualitative descriptions that could gain no credit. Some candidates obtained correct numerical values but then presented the value without a unit. Candidates should be encouraged to check whether a unit is required whenever they give a numerical answer.

(c) Many candidates earned full credit, but often the curves were drawn with insufficient care. For example, common mistakes were for candidates to draw a curve with the correct maximum potential energy at depth $h = 0.8\,\text{m}$ but this would not be matched at $h = 2.0\,\text{m}$, or the minimum of the curve was not close enough to $h = 1.4\,\text{m}$.

4(a)	$\omega = 2\pi / T$	**C1**
	$= 2\pi / (0.15 \times 10^{-6}) = 4.2 \times 10^{7}\,\text{rad s}^{-1}$	**A1**

4(b)	$a_0 = \omega^2 x_0$	**C1**
	$= (4.2 \times 10^{7})^2 \times 40 \times 10^{-6}$ $= 7.1 \times 10^{10}\,\text{m s}^{-2}$	**A1**

4(c)	$E = ½ m\omega^2 x_0^2$	**C1**
	$= ½ \times 2.4 \times 10^{-4} \times (4.2 \times 10^{7})^2 \times (40 \times 10^{-6})^2$	**C1**
	$= 340\,\text{J}$	**A1**

4(d)(i)	apply alternating p.d. (to / across crystal)	**B1**
	applying p.d. to / across crystal causes it to distort	**B1**

4(d)(ii)	$Z = \rho c$ $Z_m = 1100 \times 1600$ $(= 1.76 \times 10^{6})$ $Z_b = 1900 \times 4100$ $(= 7.79 \times 10^{6})$	**C1**
	intensity reflection co-efficient= $[(7.79 - 1.76) / (7.79 + 1.76)]^2$ $= 0.40$ or 40%	**C1**
	percentage transmitted = 60%	**A1**

Question 4

(a) Generally well-answered.

(b) This question was well-answered by the candidates who knew the starting equation.

(c) Many candidates knew the correct equation for total energy, though various errors were seen in its use. These ranged from power-of-ten errors to forgetting which quantities needed to be squared. A common error from some of the weaker candidates was to use the maximum acceleration value from the previous part as the amplitude.

(d) (i) Examiners expected to see reference to an alternating voltage applied across the crystal, making it alternately expand and contract. Many candidates confused the concepts of a voltage being applied (to cause distortion of the crystal) with a voltage being induced in the crystal by mechanical vibrations. Some candidates confused voltage with current.

(ii) Well-answered by many candidates, with full credit being common. Many other candidates calculated the percentage reflected and stopped short of using that value to determine the percentage transmitted.

5(a)	arrow from sphere, perpendicular to string, pointing left and down	**B1**

5(b)(i)	amplitude = 0.016 m	**A1**

5(b)(ii)	angular frequency = $2\pi / T$	**C1**
	$= 2\pi / 0.40$ $= 16 \text{ rad s}^{-1}$	**A1**

5(b)(iii)	total energy $= \frac{1}{2} m\omega^2 x_0^2$	**C1**
	$= \frac{1}{2} \times 0.15 \times 15.7^2 \times 0.016^2$ $= 4.7 \times 10^{-3}$ J	**A1**

5(c)	dome-shaped curve starting and ending on the x-axis, with peak at $x = 0$	**B1**
	maximum E_K shown as 4.7×10^{-3} J	**B1**
	minimum x shown as –0.016 m and maximum x shown as +0.016 m at the ends of the line	**B1**

Question 5

(a) A large number of candidates thought that the resultant force on the sphere was horizontal rather than perpendicular to the string.

(b)(i) This question was generally well answered, with most candidates correctly deducing the amplitude from the graph.

(ii) This question was also generally well answered. Some of the weaker candidates were confused between angular frequency and frequency.

(iii) Candidates that knew the syllabus equation for the energy of the oscillations were usually able to use their values in **(b)(i)** and **(b)(ii)** to calculate the energy correctly.

(c) This was a well answered question by candidates that understood this part of the syllabus, with many achieving full credit.

4(a)	(motion in which) acceleration is (directly) proportional to displacement	**B1**
	(motion in which): acceleration is (always) in the opposite <u>direction</u> to displacement **or** acceleration is (always) <u>directed</u> towards a fixed point	**B1**

4(b)(i)	amplitude $= (9.5 - 3.5) / 2$ $= 3.0$ cm	**A1**

4(b)(ii)	$\omega = v_0 / x_0$	**C1**
	$= 9.5 / 3.0 = 3.2$ rad s^{-1}	**A1**

4(b)(iii)	$T = 2\pi / \omega$	**C1**
	$= 2\pi / 3.2$ $= 2.0$ s	**A1**

4(b)(iv)	attempted sinusoidal curve starting with a minimum at $t = 0$	**B1**
	sinusoidal curve of period 2.0 s from $t = 0$ to $t = 6.0$ s	**B1**
	all peaks shown at $h = 9.5$ cm	**B1**
	all troughs shown at $h = 3.5$ cm	**B1**

NOT FOUND:

9702_w24_qp_41 EXAMINER REPORT (Qu 4)

4(a)	straight line through the origin shows that *a* is proportional to *x*	**B1**
	negative gradient shows that *a* and *x* are (always) in opposite <u>directions</u>	**B1**

4(b)(i)	$a = -\omega^2 x$ $\omega = \sqrt{(2A / 3Y)}$	**A1**

4(b)(ii)	$v_0 = \omega x_0$	**C1**
	$= 3Y \times \sqrt{(2A / 3Y)}$ $= \sqrt{(6AY)}$	**A1**

4(b)(iii)	$E = \frac{1}{2} m\omega^2 x_0^2$	**C1**
	$= \frac{1}{2} m \times (2A / 3Y) \times (3Y)^2$ $= 3mAY$	**A1**

4(c)	$\omega = 2\pi / T$ $(= 2\pi / 0.75)$	**C1**
	$x = 1.8 \sin (8.4\, t)$	**A1**

Question 4

(a) Many candidates answered a different question from the one that was asked. The question did not ask candidates to define simple harmonic motion; it asked candidates to explain how the graph shows that the motion of the block is simple harmonic, and so answers relating to features of the graph were expected.

(b) Common mistakes in **(i)** were either to forget to take the square root of the expression for ω^2 or to include a minus sign inside the square root. Many weaker candidates took the amplitude and maximum acceleration as Y and A, respectively, rather than $3Y$ and $2A$ as given in the question.

In **(ii)** and **(iii)**, many candidates knew the equations for maximum speed and total energy, but made mistakes in the algebra in arriving at a concise answer in terms of A and Y. Some candidates left the answers in terms of other letters such as ω, and therefore did not answer the question.

(c) This was well answered by many candidates.

4(a)	oscillation (of object) at maximum amplitude	**B1**
	when driving frequency = natural frequency (of system)	**B1**
4(b)(i)	light damping	**B1**
4(b)(ii)	<u>oscillations</u> (of ball) lose energy	**B1**
	(due to) resistive forces (acting on ball)	**B1**
4(b)(iii)	frequency = 1 / 0.25 = 4.0 Hz	**A1**
4(c)	curve showing a maximum amplitude at a single non-zero frequency	**B1**
	single maximum amplitude shown at 4.0 Hz	**B1**

Question 4

(a) The majority of the candidates gave very good explanations of the matching of driving and natural frequencies in resonance. Fewer were able to explain that the oscillations reach maximum amplitude. Some weaker candidates did not mention oscillations at all.

(b) (i) Although most candidates identified the phenomenon as damping, a significant number of those did not give a complete answer including the type of damping.

(ii) Most candidates appreciated the role of resistive forces in damping, but few described the oscillations having their energy reduced as the cause of the amplitude reduction.

(iii) The majority of candidates correctly read the period from the graph and calculated the frequency from that value.

(c) Only the stronger candidates were able to sketch the resonance curve. Where that was done, it generally peaked at the correct frequency. Candidates would benefit from further study of this aspect of resonance.

3(a)	$E = \frac{1}{2} m\omega^2 x_0^2$	**C1**
	$2.2 \times 10^{-4} = \frac{1}{2} \times 24 \times 10^{-3} \times (14 \times 10^{-3} / 4)^2 \times \omega^2$	**C1**
	$\omega = 39\ \text{rad s}^{-1}$	**A1**

3(b)(i)	use of acceleration = $9.81\ \text{m s}^{-2}$ $x_0 = 9.81 / 39^2$	**C1**
	$= 6.4 \times 10^{-3}$ m	**A1**

3(b)(ii)	at top of oscillation	**B1**
	any one point from: where the downward acceleration first exceeds free-fall acceleration where the greatest downwards acceleration occurs where the resultant force is the maximum downwards where the contact force is a minimum	**B1**

NOT FOUND:

9702_m24_qp_42 EXAMINER REPORT (Qu 3)

4(a)(i)	amplitude $= \frac{1}{2} \times 7.2 \times 10^{-15}$ $= 3.6 \times 10^{-15}$ m	**A1**

4(a)(ii)	$\omega = 2\pi / (0.20 \times 10^{-6})$ $= 3.1 \times 10^{7}$ rad s^{-1}	**A1**

4(a)(iii)	$v_0 = \omega x_0$	**C1**
	$v_0 = 3.1 \times 10^{7} \times 3.6 \times 10^{-15} = 1.1 \times 10^{-7}$ m s^{-1}	**A1**

4(b)(i)	$I_0 = nAv_0e$ $= 8.5 \times 10^{28} \times 4.3 \times 10^{-4} \times 1.1 \times 10^{-7} \times 1.60 \times 10^{-19}$	**C1**
	$= 0.64$ A	**A1**

4(b)(ii)	sketch: two cycles of sinusoidal curve of amplitude I_0 and period 0.20 μs	**B1**
	correct phase, with $I = +I_0$ at $t = 0$	**B1**

4(b)(iii)	equation of form $I = I_0 \cos \omega t$	**M1**
	value of I_0 used matches answer to **(b)(i)** and value of ω used matches answer to **(a)(ii)** [if **(a)(ii)** and **(b)(i)** correct then $I = 0.64 \cos (3.1 \times 10^{7}\ t)$]	**A1**

4(b)(iv)	$I_{r.m.s.} = I_0 / \sqrt{2}$ $= 0.64 / \sqrt{2}$ $= 0.45$ A	**A1**

Question 4

(a) (i) This question was generally well answered. Among candidates that did not give the correct answer, the most common mistakes were misreading the scale, omission of the 10^{-15} factor, or forgetting to halve the peak–trough height.

(ii) There was some confusion among weaker candidates between frequency and angular frequency, but otherwise this question was well answered.

(iii) Most candidates knew or were able to deduce the correct relationship between maximum speed and amplitude for simple harmonic motion.

(b) (i) Most candidates realised that a substitution into $I = nAvq$ was required. The common mistake among the more able candidates was a power-of-ten error in the unit conversion for the area. Some of the weaker candidates attempted to square the area, and a small number did not know that the value of q required was the elementary charge.

(ii) Most candidates realised that a sinusoidal curve was required with an amplitude I_0 and a period of $0.20\,\mu s$. Many candidates found it difficult to draw the curve with the correct curvature in the different parts of the graph. The stronger candidates were generally able to deduce that the current has the largest magnitude when the electrons are moving with the fastest speed and therefore draw a curve with the correct phase.

(iii) Many candidates found this question difficult. Partial credit was awarded to candidates who substituted their values from **(a)(ii)** and **(b)(i)** into $I = I_0 \sin \omega t$ but, as with **(b)(ii)**, it was generally only the stronger candidates that realised it was a cosine rather than sine equation that was required here.

(iv) This question was generally well answered.

4(a)	(motion in which) acceleration is (directly) proportional to displacement	**B1**
	(motion in which): acceleration is (always) in the opposite <u>direction</u> to displacement **or** acceleration is (always) directed towards a fixed point	**B1**

4(b)(i)	$\omega = 2\pi / T$	**C1**
	$\omega = 2\pi / 3.0$ $= 2.1\ \text{rad s}^{-1}$	**A1**

4(b)(ii)	$E = \frac{1}{2} m\omega^2 x_0^2$	**C1**
	$= \frac{1}{2} \times 0.81 \times 2.1^2 \times 0.036^2$ $= 2.3 \times 10^{-3}\ \text{J}$	**A1**

4(c)	sketch: line starting at (0, 0.036) and not reaching $x = \pm\ 0.036$ m at any other time	**B1**
	smooth curve, with no sudden changes in gradient, showing continuously decreasing magnitude of x from maximum displacement at $t = 0$ to final displacement of zero where the gradient is also zero	**B1**
	displacement reaches final value of zero between $t = 0.75$ s and $t = 3.0$ s at the latest	**B1**

NOT FOUND:

9702_w23_qp_41 EXAMINER REPORT (Qu 4)

4(a)(i)	$\omega = 2\pi f$	**C1**
	$f = 9.7 / 2\pi$ $= 1.5$ Hz	**A1**
4(a)(ii)	amplitude = $\sqrt{(11.6)} = 3.4$ cm	**A1**
4(a)(iii)	$a_0 = \omega^2 x_0$	**C1**
	$= 9.7^2 \times 3.4 \times 10^{-2}$ $= 3.2$ m s^{-2}	**A1**
4(b)	sketch: straight line through the origin with negative gradient	**B1**
	line with negative gradient passing through (+3.4, $-a_0$) and (–3.4, $+a_0$)	**B1**
	line with ends at $x = \pm$ 3.4 cm and $a = \pm a_0$	**B1**
4(c)	sum of potential energy and kinetic energy is constant	**B1**
	at maximum displacement, kinetic energy is zero **or** at maximum displacement, potential energy is maximum	**B1**
	at zero displacement, kinetic energy is maximum **or** at zero displacement, potential energy is minimum	**B1**

Question 4

(a) (i) This question was generally well answered.

(ii) This question was also generally well answered.

(iii) Most candidates correctly recalled the equation linking maximum acceleration and amplitude, although some gave the general equation for simple harmonic motion and were not awarded credit for the equation until it was clear that the maximum value of displacement was the value substituted. A common error was to neglect the power of ten conversion from cm to m, and to obtain an answer of $320\,m\,s^{-2}$.

(b) Many closed loops were seen from weaker candidates who were confusing acceleration with velocity. Most of the more able candidates appreciated that the acceleration–displacement graph for simple harmonic motion is a straight line through the origin with negative gradient. Some candidates did not take sufficient care to ensure that the line reached the maximum values of *a* and *x* with the required half-square accuracy. Many other candidates did not appreciate that the line had to end at those points, and not continue past the maximum values.

(c) Of the three extended writing questions in this paper, this question was answered the most successfully. Candidates were asked to describe the interchange of kinetic and potential energy of the oscillations. Credit was available for stating where in the oscillation each form of energy is a maximum and when it is zero, and that at any stage in the oscillation the sum of the kinetic and potential energies remains constant. A common misconception among weaker candidates was to confuse the potential energy of the oscillations with gravitational or elastic potential energy individually (not appreciating that the potential energy of the oscillations is the sum of the two). Responses to the effect that the potential energy is maximum at the top of the oscillations and minimum at the bottom could not be awarded credit. Correct use of technical terms was difficult for some candidates, with the terms amplitude and displacement being commonly conflated.

3(a)	P: total energy Q: potential energy R: kinetic energy	B2

3(b)	$E = ½m\omega^2 x_0^2$ **or** $E = ½mv_0^2$ **and** $v_0 = \omega x_0$	C1
	$6.4 \times 10^{-3} = \frac{1}{2} \times 0.130 \times \omega^2 \times 0.015^2$ ($\omega^2 = 438$) ($\omega = 20.9$)	C1
	$T = 2\pi / \omega$	C1
	$= 2\pi / 20.9$ $= 0.30$ s	A1

3(c)(i)	resistive forces	B1

3(c)(ii)	0.92^6	C1
	decrease in energy $= 6.4 - (6.4 \times 0.92^6)$ $= 2.5$ mJ	A1

3(c)(iii)	light damping because the amplitude of oscillations gradually reduces **or** light damping because the system still oscillates	B1

Question 3

(a) Most candidates correctly identified line P as the total energy of the oscillations. Many identified Q and R correctly as well, but some reversed the energy types. A few qualified the type of potential energy, such as elastic potential energy, but this was incorrect as there are changes in both elastic and gravitational potential energy.

(b) There were a good number of correct answers here. However, many candidates incorrectly decided that a one significant figure answer was appropriate. Candidates are reminded of the general advice that they should base the number of significant figures to which they present their answer on the precision of the data in the question.

(c) (i) Most candidates were able to give the cause of damping.

(ii) This calculation proved to be challenging. Common errors were to use $6 \times 8\%$ of the 6.4 mJ, to use 0.08^6 or to omit the subtraction from the total energy when using the correct energy fraction.

(iii) Many candidates were able to identify the type of damping as light but were unable to give a convincing reason for this conclusion. The fact that energy is lost slowly and that it takes time to return to equilibrium is just as true for heavy damping as it is for light damping, and candidates needed to give a clear indication that the continuation of the oscillations is the basis for the conclusion.

4(a)(i)	$x_0 = 8.0\ \text{cm}$	**A1**

4(a)(ii)	$\omega = 2\pi / T$	**C1**
	$= 2\pi / 4.0 = 1.6\ \text{rad s}^{-1}$	**A1**

4(a)(iii)	$E = \frac{1}{2}m\omega^2 x_0^2$	**C1**
	$= \frac{1}{2} \times 36 \times 1.6^2 \times 0.080^2$	**C1**
	$= 0.29\ \text{J}$	**A1**

4(b)	dome-shaped curve, starting and ending at $E_K = 0$	**B1**
	maximum E_K shown as 0.29 J	**B1**
	position of peak shown at $h = 10.0\ \text{cm}$	**B1**
	line intercepts h-axis at $h = 2.0\ \text{cm}$ and at $h = 18.0\ \text{cm}$	**B1**

Question 4

(a) (i) Most candidates were able to use the height–time graph to deduce that the amplitude of the oscillations is 8.0 cm.

(ii) This question was also well answered, with most candidates able to apply the period of 4.0 s to the equation for ω.

(iii) This question proved to be more of a challenge to many candidates who were unable to recall correctly the equation for the total energy of an oscillating system. Of those who did know the equation, a variety of mistakes were seen in the calculation, including not squaring the amplitude, forgetting to convert the amplitude into metres, and arithmetic errors due to premature intermediate rounding.

(b) The mark scheme was structured in such a way as to allow most candidates to obtain at least partial credit by getting different aspects of the curve right. Many candidates were able to be awarded full credit.

3(a)	$a = -\omega^2 x$	M1
	a = acceleration, x = displacement from equilibrium position and ω = angular frequency	A1

3(b)(i)	$x_0 = 0.12$ m	A1

3(b)(ii)	$v = \omega\sqrt{(x_0^2 - x^2)}$ two (x, v) pairs correctly read from Fig. 3.2 (one may be (x_0, 0) or value of x_0 from **(i)**)	C1
	e.g. $0.20 = \omega\sqrt{(0.12^2 - 0)}$ leading to $\omega = 1.7$ rad s^{-1}	A1

3(b)(iii)	$E = ½M\omega^2 x_0^2$	C1
	$0.050 = ½ \times M \times 1.67^2 \times 0.12^2$ $M = 2.5$ kg	A1
	or	
	$(E_K)_{max} = ½Mv_0^2$	(C1)
	$0.050 = ½\ M \times 0.20^2$ $M = 2.5$ kg	(A1)

3(c)(i)	loss of (total) energy (of system)	B1
	due to resistive forces	B1

3(c)(ii)	closed loop surrounding the origin with maximum x at ± 0.060 m passing through $v = 0$	**B1**
	maximum velocity shown as ± 0.10 m s^{-1} passing through $x = 0$	**B1**

Question 3

(a) Most candidates were able to state the defining equation for simple harmonic motion. Some candidates were insufficiently precise and described x only as displacement, rather than displacement from the equilibrium position.

(b) (i) The majority of the candidates correctly determined the amplitude of the oscillations from the graphs.

(ii) The majority of the candidates showed how to reach the angular frequency of the oscillations.

(iii) There were many correct answers here. The most common misconception was to consider gravitational potential energy alone to find the mass of the object. This ignored the potential energy changes in the spring. Use of the equation for the total energy of simple harmonic oscillations $E = \frac{1}{2}M\omega^2 x_0^2$ was the most reliable approach here.

(c) (i) Most candidates gained full credit for stating what is meant by damping.

(ii) Many candidates drew the correct graph here. Some only changed one out of the velocity and the displacement (whereas both will be affected by the presence of damping). Some drew shapes that appeared to be unrelated to the original ellipse provided.