Q1.

3 (a) f_0 is at natural frequency of spring (system) B1
this is at the driver frequency .... B1 [2]
(allow 1 mark for recognition that this is resonance)

(b) line: amplitude less at all frequencies B1
peak flatter B1
peak at f_0 or slightly below f_0........ B1 [3]

(c) (aluminium) sheet cuts the magnetic flux/field........ B1
(so) currents/e.m.f. induced in the (metal) sheet B1
these currents dissipate energy M1
less energy available for the oscillations A1
so amplitude smaller .... A0 [4]
('current opposes motion of sheet' scores one of the last two marks)

Q2.

4	(a)	e.g. amplitude is not constant or wave is damped *do not allow 'displacement constant'*	B1	
		should be (-)cos, (not sin)	B1	[2]
	(b)	T = 0.60 s	C1	
		$\omega = 2\pi/T$ = 10.5 rad s^{-1} *(allow 10.4 → 10.6)*	A1	[2]
	(c)	same period	B1	
		displacement always less	M1	
		amplitude reducing appropriately *for 2nd and 3rd marks, ignore the first quarter period*	A1	[3]
		Total		[7]

Q3.

4	(a)	acceleration proportional to displacement (from a fixed point) or $a = -\omega^2 x$ with a, ω and x explained	M1	
		and directed towards a fixed point or negative sign explained	A1	[2]
	(b)	for s.h.m., $a = (-)\omega^2 x$	B1	
		identifies ω^2 as $A\rho g/M$ and therefore s.h.m. (may be implied)	B1	
		$2\pi f = \omega$	B1	
		hence $f = \dfrac{1}{2\pi}\sqrt{\dfrac{A\rho g}{M}}$	A0	[3]
	(c) (i)	T = 0.60 s or f = 1.7 Hz	C1	
		$0.60 = (2\pi\sqrt{M})/\sqrt{(\pi \times \{1.2 \times 10^{-2}\}^2 \times 950 \times 9.81)}$	C1	
		M = 0.0384 kg	A1	[3]
	(ii)	decreasing peak height/amplitude	B1	[1]

Q4.

4	(a)	(i)	1.0	B1	[1]
		(ii)	40 Hz	B1	[1]
	(b)	(i)	speed $= 2\pi fa$	C1	
			$= 2\pi \times 40 \times 42 \times 10^{-3}$		
			$= 10.6\ \text{m s}^{-1}$	A1	[2]
		(ii)	acceleration $= 4\pi^2 f^2 a$	C1	
			$= (80\pi)^2 \times 42 \times 10^{-3}$		
			$= 2650\ \text{m s}^{-2}$	A1	[2]
	(c)	(i)	S marked correctly (on 'horizontal line through centre of wheel)	B1	
		(ii)	A marked correctly (on 'vertical line' through centre of wheel)	B1	[2]

Q5.

7	(a)	(i)	oscillations are damped/amplitude decreases	B1	
			as magnet moves, flux is cut by coil	B1	
			e.m.f./current is induced in the coil	B1	
			causing energy loss in load OR force on magnet	B1	
			energy is derived from oscillations of magnet OR force opposes motion of magnet	B1	[5]
		(ii)	$T = 0.60$ s	C1	
			$\omega_0\ (= 2\pi/T) = 10.5\ \text{rad s}^{-1}$	A1	[2]
	(b)		sketch: sinusoidal wave with period unchanged or slightly smaller	M1	
			same initial displacement, less damping	A1	[2]
	(c)	(i)	sketch: general shape – peaked curve	M1	
			peak at ω_0 and amplitude never zero	A1	[2]
		(ii)	resonance	B1	[1]
		(iii)	useful: e.g. child on swing, microwave oven heating	B1	
			avoid: e.g. vibrating panels, vibrating bridges	B1	[2]
			(*for credit, stated example must be put in context*)		

Q6.

3	(a)	(i)	amplitude = 0.5 cm	A1	[1]
		(ii)	period = 0.8 s	A1	[1]
	(b)	(i)	$\omega = 2\pi / T$	C1	
			$= 7.85$ rad s^{-1}		
			correct use of $v = \omega \sqrt{(x_0^2 - x^2)}$	B1	
			$= 7.85 \times \sqrt{(\{0.5 \times 10^{-2}\}^2 - \{0.2 \times 10^{-2}\}^2)}$		
			$= 3.6$ cm s^{-1}	A1	[3]
			(if tangent drawn or clearly implied (B1)		
			3.6 ± 0.3 cm s^{-1} (A2)		
			but allow 1 mark for > ±0.3 but ≤ ±0.6 cm s^{-1})		
		(ii)	$d = 15.8$ cm	A1	[1]
	(c)	(i)	(continuous) loss of energy / reduction in amplitude (from the oscillating system)	B1	
			caused by force acting in opposite direction to the motion / friction / viscous forces	B1	[2]
		(ii)	same period / small increase in period	B1	
			line displacement always less than that on Fig.3.2 *(ignore first 1/4)*	M1	
			peak progressively smaller	A1	[3]

Q7.

3	(a)	(i)	to-and-fro / backward and forward motion (between two limits)	B1	[1]
		(ii)	no energy loss or gain / no external force acting / constant energy / constant amplitude	B1	[1]
		(iii)	acceleration directed towards a fixed point	B1	
			acceleration proportional to distance from the fixed point / displacement	B1	[2]
	(b)		acceleration is constant (magnitude)	M1	
			so cannot be s.h.m.	A1	[2]

Q8.

2 (a) (i)	reduction in energy (of the oscillations)	(B1)	
	reduction in amplitude / energy of oscillations	(B1)	
	due to force (always) opposing motion / resistive forces	(B1)	[2]
	any two of the above, max 2		
(ii)	amplitude is decreasing (very) gradually / oscillations would continue (for a long time) /many oscillations	M1	
	light damping	A1	[2]
(b) (i)	frequency = 1 / 0.3		
	= 3.3 Hz	A1	[1]
	allow points taken from time axis giving f = 3.45 Hz		
(ii)	energy = $\frac{1}{2}mv^2$ <u>and</u> $v = \omega a$	C1	
	= $\frac{1}{2} \times 0.065 \times (2\pi/0.3)^2 \times (1.5 \times 10^{-2})^2$	M1	
	= 3.2 mJ	A0	[2]
(c)	amplitude reduces exponentially / does not decrease linearly	M1	
	so will be not be 0.7 cm	A1	[2]

Q9.

3 (a)	acceleration / force proportional to displacement from a fixed point	M1	
	acceleration / force (always) directed towards that fixed point / in opposite direction to displacement	A1	[2]
(b) (i)	$A\rho g / m$ is a constant and so acceleration proportional to x	B1	
	negative sign shows acceleration towards a fixed point / in opposite direction to displacement	B1	[2]
(ii)	$\omega^2 = (A\rho g / m)$	C1	
	$\omega = 2\pi f$	C1	
	$(2 \times \pi \times 1.5)^2 = (\{4.5 \times 10^{-4} \times 1.0 \times 10^3 \times 9.81\} / m)$	C1	
	m = 50 g	A1	[4]

Q10.

4 (a)	$a = (-)\omega^2 x$ and $\omega = 2\pi/T$	C1	
	T = 0.60 s	C1	
	$a = (4\pi^2 \times 2.0 \times 10^{-2}) / (0.6)^2$		
	= 2.2 m s^{-2}	A1	[3]
(b)	sinusoidal wave with all values positive	B1	
	all values positive, all peaks at E_K and energy = 0 at t = 0	B1	
	period = 0.30 s	B1	[3]

Q11.

2	**(a)** energy $= \frac{1}{2}m\omega^2a^2$ and $\omega = 2\pi f$	C1	
	$= \frac{1}{2} \times 37 \times 10^{-3} \times (2\pi \times 3.5)^2 \times (2.8 \times 10^{-2})^2$	M1	
	$= 7.0 \times 10^{-3}$ J	A0	[2]
	(allow $2\pi \times 3.5$ shown as 7π)		
	Energy $= \frac{1}{2}mv^2$ and $v = r\omega$	(C1)	
	Correct substitution	(M1)	
	Energy $= 7.0 \times 10^{-3}$ J	(A0)	
	(b) $E_K = E_P$		
	$\frac{1}{2}m\omega^2(a^2 - x^2) = \frac{1}{2}m\omega^2x^2$ *or* E_K or E_P = 3.5 mJ	C1	
	$x = a/\sqrt{2} = 2.8/\sqrt{2}$ *or* $E_K = \frac{1}{2}m\omega^2(a^2 - x^2)$ *or* $E_P = \frac{1}{2}m\omega^2x^2$	C1	
	= 2.0 cm	A1	[3]
	(E_K or E_P = 7.0 mJ scores 0/3)		
	Allow: $k = 17.9$	(C1)	
	$E = \frac{1}{2}kx^2$	(C1)	
	$x = 2.0$ cm	(A1)	
	(c) (i) graph: horizontal line, y-intercept = 7.0 mJ with end-points of line at +2.8 cm and –2.8 cm	B1	[1]
	(ii) graph: reasonable curve	B1	
	with maximum at (0,7.0) end-points of line at (–2.8, 0) and (+2.8, 0)	B1	[2]
	(iii) graph: inverted version of **(ii)**	M1	
	with intersections at (–2.0, 3.5) and (+2.0, 3.5)	A1	[2]
	(Allow marks in **(iii)**, but not in **(ii)**, if graphs K & P are not labelled)		
	(d) gravitational potential energy	B1	[1]

Q12.

3	(a)	(i)	1. amplitude = 1.7 cm	A1	[1]
			2. period = 0.36 cm	C1	
			frequency = 1/0.36		
			= 2.8 Hz	A1	[2]
		(ii)	$a = (-)\omega^2 x$ and $\omega = 2\pi/T$	C1	
			acceleration = $(2\pi/0.36)^2 \times 1.7 \times 10^{-2}$	M1	
			= $5.2\,\text{m s}^{-2}$	A0	[2]
	(b)		graph: straight line, through origin, with negative gradient	M1	
			from $(-1.7 \times 10^{-2}, 5.2)$ to $(1.7 \times 10^{-2}, -5.2)$	A1	[2]
			(if scale not reasonable, do not allow second mark)		
	(c)		*either* kinetic energy = $\frac{1}{2}m\omega^2(x_0^2 - x^2)$		
			or potential energy = $\frac{1}{2}m\omega^2x^2$ <u>and</u> potential energy = kinetic energy	B1	
			$\frac{1}{2}m\omega^2(x_0 - x^2) = \frac{1}{2} \times \frac{1}{2}m\omega^2x_0^2$ or $\frac{1}{2}m\omega^2x^2 = \frac{1}{2} \times \frac{1}{2}m\omega^2x_0^2$	C1	
			$x_0^2 = 2x^2$		
			$x = x_0 / \sqrt{2} = 1.7 / \sqrt{2}$		
			= 1.2 cm	A1	[3]

Q13.

3	(a)	(i)	$\omega = 2\pi / T$		
			$= 2\pi / 0.69$	C1	
			$= 9.1\ \text{rad s}^{-1}$	A1	[2]
			(allow use of f = 1.5 Hz to give $\omega = 9.4\ \text{rad s}^{-1}$)		
		(ii)	1. $x = 2.1 \cos 9.1t$		
			2.1 and 9.1 numerical values	B1	
			use of cos	B1	[2]
			2. $v_0 = 2.1 \times 10^{-2} \times 9.1$ (allow ecf of value of x_0 from **(ii)1.**)		
			$= 0.19\ \text{m s}^{-1}$	B1	
			$v = v_0 \sin 9.1t$ (allow cos $9.1t$ if sin used in **(ii)1.**)	B1	[2]
	(b)		energy = either $\frac{1}{2} m v_0^2$ or $\frac{1}{2} m\omega^2 x_0^2$		
			= either $\frac{1}{2} \times 0.078 \times 0.19^2$ or $\frac{1}{2} \times 0.078 \times 9.1^2 \times (2.1 \times 10^{-2})^2$	C1	
			$= 1.4 \times 10^{-3}$ J	A1	[2]

Q14.

3 (a) (i) constant amplitude B1
(ii) period = 0.75 s ...(allow ±0.2 s).......... C1
$\omega = 2\pi/T$ C1
ω = 8.4 rad s^{-1} ...(-1 for 1 sf).......... A1
(iii) either use of gradient or $v = \omega y_0$ C1
v = 0.168 m s^{-1} .... A1 [6]
(allow ±0.02 for construction: gradient drawn at wrong place 0/2)

(b) (i) 1.3 Hz B1
(ii) at $\frac{1}{2}f_0$, 'pulse' provided to mass on alternate/some oscillations M1
so 'pulses' build up the amplitude .... A1 [3]

Q15.

2 (a) (i) a, ω and x identified ....(-1 each error or omission).......... B2
(ii) (-)ve because a and x in opposite directions
OR a directed towards mean position/centre.......... B1 [3]

(b) (i) forces in springs are $k(e + x)$ and $k(e - x)$ C1
resultant = $k(e + x) - k(e - x)$ M1
= $2kx$ .... A0 [2]

(ii) $F = ma$ B1
$a = -2kx/m$.......... A0
(-)ve sign explained.......... B1 [2]

(iii) $\omega^2 = 2k/m$.......... C1
$(2\pi f)^2 = (2 \times 120)/0.90$ C1
f = 2.6 Hz .... A1 [3]

(c) atom held in position by attractive forces
atom oscillates
not just two forces OR 3D not 1D
force not proportional to x
any two relevant points, 1 each, max 2 .... B2 [2]

Q16.

3	(a)	(i)	reasonable shape as 'inverse' of k.e. line	1	
		(ii)	straight line, parallel to x-axis at 15 mJ	1	[2]
	(b)	*either*	(max) kinetic energy (= ½ mv^2) = ½ m $\omega^2 a_0^2$	1	
			15 x 10^{-3} = ½ x 0.15 x ω^2 x (5.0 x 10^{-2})^2	1	
			ω = 8.9(4) rad s^{-1}	1	
		or	(k.e. = ½ mv^2), v = 0.44(7) m s^{-1}	1	
			ω = v/a = (0.447)/(5.0 x 10^{-2})	1	
			ω = 8.9(4) rad s^{-1}	1	[3]
	(c)	(i)	*either* loss of energy (from the system) *or* amplitude decreases *or* additional force acting (on the mass)	1	
			either continuous/gradual loss *or* force always opposing motion	1	[2]
		(ii)	*either* (now has 80% of its) p.e./k.e. = 12 mJ *or* loss in k.e. = 3 mJ	1	
			new amplitude = 4.5 cm (allow ± 0.1 cm)	1	[2]

Q17.

4	(a)(i)	$\omega = 2\pi f$ …………	C1	
		$= 2\pi \times 1400$		
		= 8800 rad s^{-1} …………	A1	[2]
	(ii)	$a_0 = (-)\omega^2 x_0$ …………	C1	
		$= (8800)^2 \times 0.080 \times 10^{-3}$		
		= 6200 m s^{-2} …………	A1	[2]
	(b)	straight line through origin with negative gradient …………	M1	
		end points of line correctly labelled …………	A1	[2]
	(c)(i)	zero displacement …………	B1	[1]
	(ii)	$v = \omega x_0$ …………	C1	
		$= 8800 \times 0.080 \times 10^{-3}$		
		= 0.70 m s^{-1} …………	A1	[2]

Q18.

3	(a)	use of $a = -\omega^2 x$ clear		C1	
		either $\omega = \sqrt{(2k/m)}$ *or* $\omega^2 = (2k/m)$		B1	
		$\omega = 2\pi f$		C1	
		$f = (1/2\pi)\sqrt{(2 \times 300)/0.240)}$		B1	
		$= 7.96 \approx 8$ Hz		A0	[4]
	(b)	(i)	resonance	B1	[1]
		(ii)	8 Hz	B1	[1]
	(c)	(increase amount of) damping		B1	
		without altering (k or) m …(some indirect reference is acceptable)		B1	
		sensible suggestion		B1	[3]

Q19.

3 (a) (i) 0.8 cm .... B1 [1]

(ii) (max.) kinetic energy = 2.56 mJ C1
$v_{(MAX)} = \omega a$ C1
(max.) kinetic energy = $\frac{1}{2}m\omega^2a^2$ or $\frac{1}{2}m\omega^2(a^2 - x^2)$ C1
$2.56 \times 10^{-3} = \frac{1}{2} \times 0.130 \times \omega^2 \times (0.8 \times 10^{-2})^2$ M1
$\omega = 24.8$ rad s^{-1} C1
$f = \omega/2\pi$ M1
= 4.0 Hz (3.95 Hz) .... A0 [6]

(b) (i) line parallel to *x*-axis at 2.56 mJ .... B1 [1]

(ii) **1** 4.0 Hz B1

2 0.50 cm (*allow ±0.03 cm*) .... B1 [2]

Q20.

3 **(a)** acceleration / force (directly) proportional to displacement	M1	
and *either* directed towards fixed point		
or acceleration & displacement in opposite directions	A1	[2]
(b) **(i)** maximum / minimum height / 8 mm above cloth / 14 mm below cloth	B1	[1]
(ii) **1.** $a = 11$ mm	A1	[1]
2. $\omega = 2\pi f$	C1	
$= 2\pi \times 4.5$		
$= 28.3$ rad s^{-1} (*do not allow 1 s.f.*)	A1	[2]

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(c) **(i)** $v = \omega a$	C1	
$= 28.3 \times 11 \times 10^{-3}$		
$= 0.31$ m s^{-1} (*do not allow 1 s.f.*)	A1	[2]
(ii) $v = \omega\sqrt{(a^2 - y^2)}$		
$y = 3$ mm	C1	
$= 28.3 \times 10^{-3}\sqrt{(11^2 - 3^2)}$	C1	
$= 0.30$ m s^{-1} (*allow 1 s.f.*)	A1	[3]

Q21.

4 (a) (i) amplitude = 0.2 mm .... A1 [1]

(ii) period = 1.2 ms C1
frequency = 830 Hz .... A1 [2]

(b) (i) any <u>two</u> of zero, 0.6 ms and 1.2 ms .... A1 [1]

(ii) any <u>two</u> of 0.3 ms, 0.9 ms, 1.5 ms .... A1 [1]

(c) *either* $v = \omega x_0 = 2\pi f x_0$
$= 2\pi \times 830 \times 0.2 \times 10^{-3} = 1.05 \text{ m s}^{-1}$
or slope of graph $= 1.0 \text{ m s}^{-1}$ ......(allow $\pm 0.1 \text{ m s}^{-1}$) C1
$E_K = \frac{1}{2}mv^2$
$= \frac{1}{2} \times 2.5 \times 10^{-3} \times 1.05^2$ C1
$= 1.4 \times 10^{-3}$ J .... A1 [3]

(d) (i) large / maximum amplitude of vibration B1
when impressed frequency equals natural frequency of vibration .... B1 [2]

(ii) e.g. metal panels on machinery vibrate / oscillate .... (M1)
motor in machine impresses frequency on panel .... (A1)
e.g. car suspension system vibrates / oscillates.................................... (M1)
going over bumps would give large amplitude vibrations .... (A1)
any feasible example, M1 + A1 .... [2]

[Total: 12]

Q22.

3 (a) straight line through origin B1
negative gradient .... B1 [2]

(b) $a = -\omega^2 x$ and $\omega = 2\pi f$ C1
$750 = (2\pi f)^2 \times 0.3 \times 10^{-3}$ C1
$f = 250$ Hz .... A1 [3]

(c) straight line between(-0.3,+190) and (+0.3,-190) .... A2 [2]
(*allow 1 mark for end of line incorrect by one grid square or line does not extend to +/- 0.3 mm*)

[Total: 7]

Q23.

3 (a) (i)	resonance		B1	[1]
(ii)	amplitude 16 mm <u>and</u> frequency 4.6 Hz		A1	[1]
(b) (i)	$a = (-)\omega^2 x$ and $\omega = 2\pi f$		C1	
	$a = 4\pi^2 \times 4.6^2 \times 16 \times 10^{-3}$		C1	
	$= 13.4\,\text{m s}^{-2}$		A1	[3]
(ii)	$F = ma$		C1	
	$= 150 \times 10^{-3} \times 13.4$			
	$= 2.0\,\text{N}$		A1	[2]
(c)	line always 'below' given line and never zero		M1	
	peak is at 4.6 Hz (or slightly less) and flatter		A1	[2]

Q24.

3 (a) (i)	8.0 cm		A1	[1]
(ii)	$2\pi f = 220$		C1	
	$f = 35$	(*condone unit*)	A1	[2]
(iii)	line drawn mid-way between AB and CD	(*allow* ±2 *mm*)	B1	[1]
(iv)	$v = \omega a$		C1	
	$= 220 \times 4.0$			
	$= 880\,\text{cm s}^{-1}$		A1	[2]
(b) (i)	**1.** line drawn 3 cm above AB	(*allow* ±2 *mm*)	B1	[1]
	2. arrow pointing upwards		B1	[1]
(ii)	**1.** line drawn 3 cm above AB	(*allow* ±2 *mm*)	B1	[1]
	2. arrow pointing downwards		B1	[1]
(iii)	$v = \omega\sqrt{(a^2 - x^2)}$			
	$= 220 \times \sqrt{(4.0^2 - 2.0^2)}$		C1	
	$= 760\,\text{cm s}^{-1}$		A1	[2]
	(*incorrect value for x, 0/2 marks*)			

Q25.

3 (a) (i)	<u>amplitude</u> remains constant		B1	[1]
(ii)	<u>amplitude</u> decreases gradually		M1	
	light damping		A1	[2]
(iii)	period = 0.80 s		C1	
	frequency = 1.25 Hz	(*period not 0.8 s, then 0/2*)	A1	[2]

Q26.

3	**(a)** acceleration proportional to displacement/distance from fixed point	M1	
	and in opposite directions/directed towards fixed point	A1	[2]
	(b) energy $= \frac{1}{2}m\omega^2 x_0^2$ and $\omega = 2\pi f$	C1	
	$= \frac{1}{2} \times 5.8 \times 10^{-3} \times (2\pi \times 4.5)^2 \times (3.0 \times 10^{-3})^2$	C1	
	$= 2.1 \times 10^{-5}$ J	A1	[3]
	(c) **(i)** at maximum displacement	M1	
	above rest position	A1	[2]
	(ii) acceleration $= (-)\omega^2 x_0$ and acceleration $= 9.81$ or g	C1	
	$9.81 = (2\pi \times 4.5)^2 \times x_0$		
	$x_0 = 1.2 \times 10^{-2}$ m	A1	[2]

Q27.

4	**(a)** straight line through origin	M1	
	shows acceleration proportional to displacement	A1	
	negative gradient	M1	
	shows acceleration and displacement in opposite directions	A1	[4]

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(b) **(i)** 2.8 cm	A1	[1]
(ii) *either* gradient = ω^2 and $\omega = 2\pi f$ *or* $a = -\omega^2 x$ and $\omega = 2\pi f$	C1	
gradient = 13.5 / (2.8 × 10^{-2}) = 482		
ω = 22 rad s^{-1}	C1	
frequency = (22/2π =) 3.5 Hz	A1	[3]
(c) e.g. lower spring may not be extended		
e.g. upper spring may exceed limit of proportionality / elastic limit		
(*any sensible suggestion*)	B1	[1]

Q28.

2	(a)	(i)	1. 0.1 s, 0.3 s, 0.5 s, etc (*any two*)	A1	[1]
			2. either 0, 0.4 s, 0.8 s, 1.2 s or 0.2 s, 0.6 s, 1.0 s (*any two*)	A1	[1]
		(ii)	period = 0.4 s frequency = (1/0.4 =) 2.5 Hz	C1 A1	[2]
		(iii)	phase difference = 90° *or* ½ π rad	B1	[1]
	(b)		frequency = 2.4 – 2.5 Hz	B1	[1]
	(c)		e.g. attach sheet of card to trolley increases damping / frictional force e.g. reduce oscillator amplitude reduces power/energy input to system	M1 A1 (M1) (A1)	[2]

Q29.

3	(a)	(i)	any two from 0.3(0) s, 0.9(0) s, 1.50 s (*allow 2.1 s etc.*)	B1	[1]
		(ii)	*either* $v = \omega x$ and $\omega = 2\pi/T$ $v = (2\pi/1.2) \times 1.5 \times 10^{-2}$ $= 0.079\ \text{m s}^{-1}$ *or* gradient drawn clearly at a correct position working clear to give $(0.08 \pm 0.01)\ \text{m s}^{-1}$	C1 M1 A0 (C1) (M1) (A0)	[2]

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	(b)	(i)	sketch: <u>curve</u> from (±1.5, 0) passing through (0, 25) reasonable shape (*curved with both intersections between* $y = 12.0 \rightarrow 13.0$)	M1 A1	[2]
		(ii)	at max. amplitude potential energy is total energy total energy = 4.0 mJ	B1 B1	[2]

Q30.

4 (a) kinetic (energy)/KE/E_K B1 [1]

(b) *either* change in energy = 0.60 mJ
or max E proportional to (amplitude)^2/equivalent numerical working B1
new amplitude is 1.3 cm B1
change in amplitude = 0.2 cm B1 [3]

Q31.

4 (a) acceleration/force proportional to displacement (from a fixed point) M1
either acceleration and displacement in opposite directions
or acceleration always directed towards a fixed point A1 [2]

(b) (i) g and r are constant so a is proportional to x B1
negative sign shows a and x are in opposite directions B1 [2]

(ii) $\omega^2 = g / r$ and $\omega = 2\pi / T$ C1
$\omega^2 = 9.8 / 0.28$
$= 35$ C1
$T = 2\pi / \sqrt{35} = 1.06$ s
time interval $\tau = 0.53$ s A1 [3]

(c) sketch: time period constant (or increases very slightly) M1
drawn line always 'inside' given loops A1
successive decrease in peak height A1 [3]

Q32.

1 (a) (i) *either* $\omega = 2\pi / T$ *or* $\omega = 2\pi f$ and $f = 1 / T$ C1
$\omega = 2\pi / 0.30$
$= 20.9$ rad s^{-1} (*accept 2 s.f.*) A1 [2]

(ii) kinetic energy $= \frac{1}{2} m\omega^2 x_0^2$ *or* $v = \omega x_0$ and $\frac{1}{2} mv^2$ C1
$= \frac{1}{2} \times 0.130 \times 20.9^2 \times (1.5 \times 10^{-2})^2 = 6.4 \times 10^{-3}$ J A1 [2]

(b) (i) as magnet moves, flux is cut by cup/aluminium giving rise to induced e.m.f. (in cup) B1

induced e.m.f. gives rise to currents and heating of the cup B1
thermal energy derived from oscillations of magnet so amplitude decreases B1
or
induced e.m.f. gives rise to currents which generate a magnetic field (B1)
the magnetic field opposes the motion of the magnet so amplitude decreases (B1) [3]

(ii) *either* use of $\frac{1}{2} m\omega^2 x_0^2$ and $x_0 = 0.75$ cm *or* x_0 is halved so ¼ energy C1
to give new energy = 1.6 mJ

either loss in energy = 6.4 – 1.6 *or* loss = ¾ × 6.4 giving loss = 4.8 mJ A1 [2]

(c) $q = mc\Delta\theta$
$4.8 \times 10^{-3} = 6.2 \times 10^{-3} \times 910 \times \Delta\theta$ C1
$\Delta\theta = 8.5 \times 10^{-4}$ K A1 [2]

Q33.

4	(a) acceleration/force proportional to displacement (from a fixed point) *either* acceleration and displacement in opposite directions *or* acceleration always directed towards a fixed point	M1 A1	[2]
	(b) (i) zero & 0.625 s *or* 0.625 s & 1.25 s *or* 1.25 s & 1.875 s *or* 1.875 s & 2.5 s	A1	[1]
	(ii) 1. $\omega = 2\pi / T$ and $v_0 = \omega x_0$	C1	
	$\omega = 2\pi / 1.25$ $= 5.03\text{ rad s}^{-1}$	C1	
	$v_0 = 5.03 \times 3.2$ $= 16.1\text{ cm s}^{-1}$ (*allow 2 s.f.*)	A1	[3]
	2. $v = \omega\sqrt{(x_0^2 - x^2)}$		
	either $\tfrac{1}{2}\omega a = \omega\sqrt{(x_0^2 - x^2)}$ *or* $\tfrac{1}{2} \times 16.1 = 5.03\sqrt{(3.2^2 - x^2)}$	C1	
	$x_0^2/4 = x_0^2 - x^2$; $2.58 = 3.2^2 - x^2$ $x = 2.8\text{ cm}$; $x = 2.8\text{ cm}$	A1	[2]
	(c) sketch: loop with origin at its centre correct intercepts & shape based on **(b)(ii)**	M1 A1	[2]