CAMBRIDGE INTERNATIONAL AS & A LEVEL PHYSICS · 9702

PHYSICS



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17 OSCILLATIONS

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82. 9702_w16_MS_43 Q: 2

(a) (i) $p \propto T$ *or* pV/T = constant *or* $pV = nRT$ C1

T (= 5 × 300 =) 1500 K A1 [2]

(ii) $pV = nRT$

$1.0 \times 10^5 \times 4.0 \times 10^{-4} = n \times 8.31 \times 300$
or
$5.0 \times 10^5 \times 4.0 \times 10^{-4} = n \times 8.31 \times 1500$ C1

n = 0.016 mol A1 [2]

(b) (i) 1. heating/thermal energy supplied B1

2. work done on/to system B1 [2]

(ii) 1. 240 J A1

2. same value as given in **1.** (= 240 J) **and** zero given for **3.** A1

3. zero A1 [3]

83. 9702_m21_MS_42 Q: 4

	Answer	Marks
(a)	acceleration and displacement are in opposite directions	**B1**
(b)(i)	$F = kx$ $= 8.0 \times (0.060 - 0.048)$ *or* $8.0 \times (0.060 + 0.048)$ or 8.0×0.012 *or* 8.0×0.108	**M1**
	$\Sigma F = (8.0 \times 0.012) - (8.0 \times 0.108) = 0.77\,N$ or $\Sigma F = 0.864 - 0.096 = 0.77\,N$	**A1**

	Answer	Marks
(b)(ii)	$a = \frac{F}{m}$ $= \frac{0.77}{0.25}$ $= 3.1 m s^{-2}$	A1
(b)(iii)	$a = -\omega^2 x$ $\omega = \sqrt{\frac{3.1}{0.048}}$ $\omega = 8.04$	C1
	$T = 2\pi / \omega$	C1
	T = 2π / 8.04 = 0.78 s	A1
(b)(iv)	(resultant) force halved and distance halved	B1
	same T	B1

84. 9702_s21_MS_43 Q: 3

	Answer	Marks
(a)	acceleration (directly) proportional to displacement	B1
	acceleration is in opposite direction to displacement	B1
(b)	$\omega^2 = 2k / m$ **and** $\omega = 2\pi f$	C1
	$(2\pi f)^2 = (2 \times 130) / 0.84$	C1
	$f = 2.8$ Hz	A1
(c)(i)	resonance	B1
(c)(ii)	oscillator supplies energy (continuously)	B1
	energy of trolley constant so energy must be dissipated **or** without loss of energy the amplitude would continuously increase	B1

85. 9702_s20_MS_41 Q: 3

	Answer	Marks
(a)(i)	amplitude = 4.9 cm	A1
(a)(ii)	frequency = 2700 / 60 = 45 Hz	A1
(a)(iii)	$v_0 = x_0\omega$ **and** $\omega = 2\pi f$	C1
	$v_0 = 4.9 \times 10^{-2} \times 2\pi \times 45$ $= 14$ m s^{-1}	A1
(a)(iv)	$v = \omega (x_0^2 - x^2)^{½}$ $= 2\pi \times 45 \times [(4.9 \times 10^{-2})^2 - (2.6 \times 10^{-2})^2]^{½}$	C1
	$= 12$ m s^{-1}	A1

	Answer	Marks
(b)	$F = ma$ **and** $a_0 = v_0\omega$ **or** $a_0 = x_0\omega^2$	**C1**
	$F = 0.64 \times 13.9 \times 2\pi \times 45$ **or** $0.64 \times 4.9 \times (2\pi \times 45)^2$	**C1**
	$= 2500$ N	**A1**

86. 9702_s20_MS_43 Q: 3

	Answer	Marks
(a)(i)	amplitude = 4.9 cm	**A1**
(a)(ii)	frequency $= 2700 / 60$ $= 45$ Hz	**A1**
(a)(iii)	$v_0 = x_0\omega$ **and** $\omega = 2\pi f$	**C1**
	$v_0 = 4.9 \times 10^{-2} \times 2\pi \times 45$ $= 14$ m s^{-1}	**A1**
(a)(iv)	$v = \omega(x_0^2 - x^2)^{½}$ $= 2\pi \times 45 \times [(4.9 \times 10^{-2})^2 - (2.6 \times 10^{-2})^2]^{½}$	**C1**
	$= 12$ m s^{-1}	**A1**

	Answer	Marks
(b)	$F = ma$ **and** $a_0 = v_0\omega$ **or** $a_0 = x_0\omega^2$	**C1**
	$F = 0.64 \times 13.9 \times 2\pi \times 45$ **or** $0.64 \times 4.9 \times (2\pi \times 45)^2$	**C1**
	$= 2500$ N	**A1**

87. 9702_m19_MS_42 Q: 3

	Answer	Marks
(a)(i)	mention of upthrust and weight	**B1**
(a)(ii)	upthrust is greater than the weight	**B1**
	(resultant force is) upwards	**B1**
(b)	A, ρ, g *and* M are constant	**B1**
	either acceleration $\propto$ – displacement *or* acceleration $\propto$ displacement and (– sign indicates) a and x in opposite directions	**B1**
(c)(i)	*either* $\omega = 2\pi / T$ *or* $\omega = 2\pi f$ and $f = 1 / T$	**C1**
	$\omega = 2\pi / 1.3$ $= 4.8$ rad s^{-1}	**A1**
(c)(ii)	$\omega^2 = A\rho g / m$	**C1**
	$4.83^2 = (4.5 \times 10^{-4} \times \rho \times 9.81) / 0.17$	**C1**
	$\rho = 900$ kg m^{-3}	**A1**

88. 9702_w19_MS_41 Q: 4

	Answer	Marks
(a)(i)	distance from a (reference) point in a given direction	B1
(a)(ii)	line is not straight **or** gradient is not constant	B1
(b)(i)	0.85–0.90 cm	A1
(b)(ii)	$a = -(2\pi f)^2 x$	C1
	e.g. $1.2 = 4\pi^2 \times f^2 \times (0.90 \times 10^{-2})$	C1
	$f = 1.8$ Hz	A1
(c)	complete circle/ellipse enclosing the origin	B1
	closed shape passing through (0, $\pm v_0$) and ($\pm x_0$, 0)	B1

89. 9702_w19_MS_43 Q: 4

	Answer	Marks
(a)(i)	distance from a (reference) point in a given direction	B1
(a)(ii)	line is not straight **or** gradient is not constant	B1
(b)(i)	0.85–0.90 cm	A1
(b)(ii)	$a = -(2\pi f)^2 x$	C1
	e.g. $1.2 = 4\pi^2 \times f^2 \times (0.90 \times 10^{-2})$	C1
	$f = 1.8$ Hz	A1
(c)	complete circle/ellipse enclosing the origin	B1
	closed shape passing through (0, $\pm v_0$) and ($\pm x_0$, 0)	B1

90. 9702_s18_MS_41 Q: 2

	Answer	Marks
(a)(i)	straight line through origin indicates acceleration $\propto$ displacement	B1
	negative gradient shows acceleration and displacement are in opposite directions	B1
(a)(ii)	$a = -\omega^2 y$ **and** $\omega = 2\pi f$ $4.5 = (2\pi \times f)^2 \times 8.0 \times 10^{-3}$ *(or other valid read-off)*	C1
	$f = 3.8$ Hz	A1
(b)(i)	maximum displacement upwards/above rest/above the equilibrium position	B1
(b)(ii)	(just leaves plate when) acceleration = $9.81\,\text{m s}^{-2}$	C1
	$9.81 = (2\pi \times 3.8)^2 \times y_0$ **or** $9.81 = 563 \times y_0$	C1
	amplitude = 17 mm	A1

91. 9702_s18_MS_43 Q: 2

	Answer	Marks
(a)(i)	straight line through origin indicates acceleration ∝ displacement	B1
	negative gradient shows acceleration and displacement are in opposite directions	B1
(a)(ii)	$a = -\omega^2 y$ **and** $\omega = 2\pi f$ $4.5 = (2\pi \times f)^2 \times 8.0 \times 10^{-3}$ *(or other valid read-off)*	C1
	$f = 3.8$ Hz	A1
(b)(i)	maximum displacement upwards/above rest/above the equilibrium position	B1
(b)(ii)	(just leaves plate when) acceleration = $9.81\,\text{m s}^{-2}$	C1
	$9.81 = (2\pi \times 3.8)^2 \times y_0$ **or** $9.81 = 563 \times y_0$	C1
	amplitude = 17 mm	A1

92. 9702_w18_MS_41 Q: 2

	Answer	Marks
(a)	sum of potential and kinetic energies (of molecules/atoms/particles)	B1
	(energy of) molecules/atoms/particles in random motion	B1
(b)(i)	final temperature = initial temperature	B1
	no change in internal energy	B1
(b)(ii)	**1.** work done on gas (P→Q): 0	A1
	increase in internal energy (P→Q): (+)97.0 J	A1
	2. increase in internal energy (Q→R): –42.5 J	A1
	3. increase in internal energy (R→P): –54.5 J	A1
	thermal energy supplied (R→P): –91.5 J	A1

93. 9702_w17_MS_41 Q: 2

	Answer	Marks
(a)	(angular frequency =) 2π × frequency **or** 2π/period	B1
(b)(i)	**1.** displacement = 2.0 cm	A1
	2. amplitude = 1.5 cm	A1
(b)(ii)	reference to displacement of oscillations **or** displacement from equilibrium position **or** displacement from 2.0 cm	B1
	straight line indicates acceleration ∝ displacement	B1
	negative gradient shows acceleration and displacement are in opposite directions	B1

	Answer	Marks
(b)(iii)	ω^2 = (–)1 / gradient **or** ω^2 = (–)$\Delta a / \Delta s$ **or** a = (–)$\omega^2 x$ and correct value of x	**C1**
	= e.g. (1.8 / 0.03) or (0.9 / 0.015) or (1.2 / 0.02) etc. **or** 0.9 = $\omega^2 \times 0.015$ = 60	**C1**
	f = $\sqrt{60}/2\pi$ = 1.2 Hz	**A1**

94. 9702_w17_MS_42 Q: 3

	Answer	Marks
(a)(i)	angle (subtended) where arc (length) is equal to radius	**M1**
	(angle subtended) at the centre of a circle	**A1**
(a)(ii)	angular frequency = 2π × frequency **or** 2π / period	**B1**
(b)(i)	c/ML^3 is a constant so acceleration is proportional to displacement	**B1**
	minus sign shows that acceleration and displacement are in opposite directions	**B1**
(b)(ii)	$c/ML^3 = (2\pi f)^2$	**C1**
	c = $4\pi^2 \times 3.2^2 \times 0.24 \times 0.65^3$	**C1**
	= 27 kg m^3 s^{-2}	**A1**

95. 9702_w17_MS_43 Q: 2

	Answer	Marks
(a)	(angular frequency =) 2π × frequency **or** 2π / period	**B1**
(b)(i)	**1.** displacement = 2.0 cm	**A1**
	2. amplitude = 1.5 cm	**A1**
(b)(ii)	reference to displacement of oscillations **or** displacement from equilibrium position **or** displacement from 2.0 cm	**B1**
	straight line indicates acceleration ∝ displacement	**B1**
	negative gradient shows acceleration and displacement are in opposite directions	**B1**

	Answer	Marks
(b)(iii)	ω^2 = (–)1 / gradient **or** $\omega^2 = (-)\Delta a/\Delta s$ **or** $a = (-)\omega^2 x$ and correct value of x	**C1**
	= e.g. (1.8 / 0.03) or (0.9 / 0.015) or (1.2 / 0.02) etc. **or** $0.9 = \omega^2 \times 0.015$ = 60	**C1**
	$f = \sqrt{60}/2\pi$ = 1.2 Hz	**A1**

96. 9702_w16_MS_41 Q: 3

(a) $2k/m = \omega^2$ M1

$\omega = 2\pi f$ M1

$(2 \times 64 / 0.810) = (2\pi \times f)^2$ leading to $f = 2.0$ Hz A1 [3]

(b) $v_0 = \omega x_0$ *or* $v_0 = 2\pi f x_0$
or
$v = \omega(x_0^2 - x^2)^{1/2}$ and $x = 0$ C1

$v_0 = 2\pi \times 2.0 \times 1.6 \times 10^{-2}$

$= 0.20\,\text{m s}^{-1}$ A1 [2]

(c) frequency: reduced/decreased B1
maximum speed: reduced/decreased B1 [2]

97. 9702_w16_MS_42 Q: 4

(a) (i) 0.225 s and 0.525 s A1 [1]

(ii) period or $T = 0.30$ s and $\omega = 2\pi / T$ C1

$\omega = 2\pi / 0.30$

$\omega = 21\,\text{rad s}^{-1}$ A1 [2]

(iii) speed = ωx_0 or $\omega(x_0^2 - x^2)^{1/2}$ and $x = 0$ C1

$= 20.9 \times 2.0 \times 10^{-2} = 0.42\,\text{m s}^{-1}$ A1 [2]

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or

use of tangent method:
correct tangent shown on Fig. 4.2 (C1)
working e.g. $\Delta y / \Delta x$ leading to maximum speed in range (0.38–0.46) $m s^{-1}$ (A1)

(b) sketch: reasonably shaped continuous oval/circle surrounding (0,0) B1
curve passes through (0, 0.42) and (0, –0.42) B1
curve passes through (2.0, 0) and (–2.0, 0) B1 [3]

98. 9702_w16_MS_43 Q: 3

(a) $2k/m = \omega^2$ M1

$\omega = 2\pi f$ M1

$(2 \times 64 / 0.810) = (2\pi \times f)^2$ leading to $f = 2.0$ Hz A1 [3]

(b) $v_0 = \omega x_0$ *or* $v_0 = 2\pi f x_0$
or
$v = \omega(x_0^2 - x^2)^{1/2}$ and $x = 0$ C1

$v_0 = 2\pi \times 2.0 \times 1.6 \times 10^{-2}$

$= 0.20\, m s^{-1}$ A1 [2]

(c) frequency: reduced/decreased B1
maximum speed: reduced/decreased B1 [2]

99. 9702_w21_MS_42 Q: 4

	Answer	Marks
(a)	straight line through the origin	**B1**
	negative gradient	**B1**
(b)	$a = (-)\omega^2 x$ **and** $T = 2\pi / \omega$	**C1**
	e.g. $\omega = \sqrt{(0.80 / 0.12)}$ (*any correct pair of values of a and x*) ($= 2.58$ rad s^{-1})	**C1**
	$T = 2\pi / 2.58$ $= 2.4$ s	**A1**
(c)(i)	Point labelled P at one end of the line	**B1**
(c)(ii)	Point labelled Q at displacement with magnitude more than half but less than maximum	**B1**

100. 9702_s19_MS_42 Q: 3

	Answer	Marks
(a)(i)	0.10 s **or** 0.30 s **or** 0.50 s **or** 0.70 s **or** 0.90 s	**A1**
(a)(ii)	0 **or** 0.40 s **or** 0.80 s	**A1**
(b)(i)	$\omega = 2\pi / T$	**C1**
	$= 2\pi / 0.40$ $= 16\ \text{rad s}^{-1}$	**A1**
(b)(ii)	$v_0 = \omega x_0$	**C1**
	$= 15.7 \times 2.5 \times 10^{-2}$ $= 0.39\ \text{m s}^{-1}$	**A1**
	or	
	tangent drawn at steepest part and working to show attempted calculation of gradient	**(C1)**
	leading to $v_0 = 0.39\ \text{m s}^{-1}$ (*allow ± 0.15 m s*$^{-1}$)	**(A1)**
(b)(iii)	$a_0 = \omega^2 x_0$	**C1**
	$a_0 = (15.7^2 \times 2.5 \times 10^{-2})$ $= 6.2\ \text{m s}^{-2}$	**A1**
	or	
	$a_0 = \omega v_0$	**(C1)**
	$a_0 = 15.7 \times 0.39$ $= 6.2\ \text{m s}^{-2}$	**(A1)**

	Answer	Marks
(c)	period is shorter/lower	**B1**
	Any one from: • greater spring constant/stiffness • (restoring) force is greater (for any given extension) • acceleration is greater (for any given extension) • greater energy/maximum speed (for a given amplitude)	**B1**

101. 9702_m17_MS_42 Q: 3

	Answer	Marks
(a)	*m* is constant *or k* / *m* is constant <u>and</u> so acceleration / *a* proportional to displacement / *x*	**B1**
	negative sign shows that acceleration / *a* is in opposite direction to displacement / *x* *or* negative sign shows acceleration / *a* is towards fixed point	**B1**
(b)	evidence of comparison to expression to $a = -\omega^2 x$	**B1**
	$\omega^2 = k/m$ *or* $\omega^2 = 4.0/m$ hence $\omega = 2.0/\sqrt{m}$	**A1**
(c)	$E_K = \frac{1}{2} m \omega^2 x_0^2$ *or* $E_K = \frac{1}{2} m v^2$ <u>and</u> $v = \omega x_0$	**C1**
	$= \frac{1}{2} m\ (4.0/m)\ (3.0 \times 10^{-2})^2$	**C1**
	$= 1.8 \times 10^{-3}\ \text{J}$	**A1**

	Answer	Marks
(d)	new $x_0 = \sqrt{[(1.8\times10^{-3}/2)\times(2/m\times(m/4.0))]}$ *or* ($E_K \propto x_0^2$ so) new $x_0 = \sqrt{[½\times(3.0\times10^{-2})^2]}$	**C1**
	$= 2.12\times10^{-2}$ m	**A1**
(e)	flux linked to block changes / flux is cut by block which induces an e.m.f. in block	**B1**
	(eddy) currents induced in block cause heating	**B1**
	thermal / heat energy comes from (kinetic / potential) energy of oscillations / block	**B1**

102. 9702_m16_MS_42 Q: 4

(a) amplitude = 1.8 cm *and* period = 0.30 s A1 [1]

(b) $E_K = ½m\omega^2(x_0^2 - x^2)$ *or* $E_K = ½mv^2$ *and* $v = \pm\omega\sqrt{(x_0^2 - x^2)}$ C1
$= ½\times0.080\times(2\pi/0.30)^2\times[(1.8\times10^{-2})^2 - (1.2\times10^{-2})^2]$ C1
$= 3.2\times10^{-3}$ J A1 [3]

103. 9702_s21_MS_41 Q: 3

	Answer	Marks
(a)	acceleration (directly) proportional to displacement	**B1**
	acceleration is in opposite direction to displacement	**B1**
(b)	$\omega^2 = 2k/m$ **and** $\omega = 2\pi f$	**C1**
	$(2\pi f)^2 = (2\times130)/0.84$	**C1**
	$f = 2.8$ Hz	**A1**
(c)(i)	resonance	**B1**
(c)(ii)	oscillator supplies energy (continuously)	**B1**
	energy of trolley constant so energy must be dissipated **or** without loss of energy the amplitude would continuously increase	**B1**

104. 9702_s21_MS_42 Q: 3

	Answer	Marks
(a)	acceleration in opposite direction to displacement shown by – sign	**B1**
	g/L is constant	**M1**
	(so) acceleration is (directly) proportional to displacement	**A1**
(b)	$\omega^2 = g/L$	**C1**
	$\omega = 2\pi/T$ **or** $\omega = 2\pi f$ **and** $f = 1/T$	**C1**
	$(2\pi/T)^2 = 9.81/0.18$ $T = 0.85$ s	**A1**
(c)	energy $\propto x_0^2$	**C1**
	(after 3 cycles,) amplitude $= (0.94)^3 x_0$ $= 0.83x_0$	**C1**
	ratio final energy / initial energy $= 0.83^2$ $= 0.69$	**A1**

105. 9702_w21_MS_41 Q: 4

	Answer	Marks
(a)(i)	5.0 cm	A1
(a)(ii)	$\omega = 2\pi / T$ **or** $\omega = 2\pi f$ **and** $f = 1 / T$	C1
	$\omega = 2\pi / 4.0$ $= 1.6$ rad s^{-1}	A1
(a)(iii)	$v_0 = \omega x_0$	C1
	$= 1.57 \times 5.0$ $= 7.9$ cm s^{-1}	A1
(b)	• initial pull was to the right • distance from X to trolley (at equilibrium) is 20 cm • period is 4.0 s • initial motion undamped • motion becomes damped at/from 12 s • damping is light • maximum speed at 1 s, 3 s, etc. / stationary at 2 s, 4 s, etc. *Any three points, 1 mark each*	B3
(c)	sketch: closed loop encircling (20, 0)	B1
	minimum L shown as 15 cm and maximum L shown as 25 cm	B1
	minimum v shown as –7.9 cm s^{-1} and maximum v shown as +7.9 cm s^{-1}	B1

106. 9702_w21_MS_43 Q: 4

	Answer	Marks
(a)(i)	5.0 cm	A1
(a)(ii)	$\omega = 2\pi / T$ **or** $\omega = 2\pi f$ **and** $f = 1 / T$	C1
	$\omega = 2\pi / 4.0$ $= 1.6$ rad s^{-1}	A1
(a)(iii)	$v_0 = \omega x_0$	C1
	$= 1.57 \times 5.0$ $= 7.9$ cm s^{-1}	A1
(b)	• initial pull was to the right • distance from X to trolley (at equilibrium) is 20 cm • period is 4.0 s • initial motion undamped • motion becomes damped at/from 12 s • damping is light • maximum speed at 1 s, 3 s, etc. / stationary at 2 s, 4 s, etc. *Any three points, 1 mark each*	B3
(c)	sketch: closed loop encircling (20, 0)	B1
	minimum L shown as 15 cm and maximum L shown as 25 cm	B1
	minimum v shown as –7.9 cm s^{-1} and maximum v shown as +7.9 cm s^{-1}	B1

107. 9702_s20_MS_42 Q: 4

	Answer	Marks
(a)	($\omega = 2\pi / T$ and $T = 2.2$ s so) $\omega = 2\pi / 2.2 = 2.9$ rad s^{-1}	A1
(b)(i)	$\omega^2 = g / R$	C1
	$R = 9.81 / 2.86^2$ $= 1.2$ m	A1
(b)(ii)	$v_0 = \omega x_0$	C1
	$= 2.9 \times 3.0 \times 10^{-2}$ $= 0.087$ m s^{-1}	A1
(c)	smooth wave starting at 3.0 cm when $t = 0$	B1
	positions of peaks and troughs show same period (or slightly longer)	B1
	each peak and trough at lower amplitude than the previous one	B1

108. 9702_s19_MS_41 Q: 3

	Answer	Marks
(a)(i)	amplitude = 0.020 m	A1
(a)(ii)	$T = 0.60$ s	C1
	$f = 1 / T$ $= 1.7$ Hz	A1
(a)(iii)	$a = (-)\omega^2 x$ **and** [$\omega = 2\pi f$ **or** $\omega = 2\pi / T$]	C1
	$a = (4\pi^2 / 0.60^2) \times 2.0 \times 10^{-2}$ $= 2.2$ m s^{-2}	A1
(b)	$1.67 = (1 / 2\pi) \times [(24 \times 10^{-4} \times \rho \times 9.81) / 0.23]^{1/2}$	C1
	$\rho = 1.1 \times 10^3$ kg m^{-3}	A1
(c)	wave starting with a peak at (0,6)	B1
	wave with same period (or slightly greater)	B1
	peak height decreasing successively	B1

109. 9702_s19_MS_43 Q: 3

	Answer	Marks
(a)(i)	amplitude = 0.020 m	A1
(a)(ii)	T = 0.60 s	C1
	$f = 1 / T$ = 1.7 Hz	A1
(a)(iii)	$a = (-)\omega^2 x$ **and** [$\omega = 2\pi f$ **or** $\omega = 2\pi / T$]	C1
	$a = (4\pi^2 / 0.60^2) \times 2.0 \times 10^{-2}$ = 2.2 m s^{-2}	A1
(b)	$1.67 = (1 / 2\pi) \times [(24 \times 10^{-4} \times \rho \times 9.81) / 0.23]^{1/2}$	C1
	$\rho = 1.1 \times 10^3$ kg m^{-3}	A1
(c)	wave starting with a peak at (0,6)	B1
	wave with same period (or slightly greater)	B1
	peak height decreasing successively	B1

110. 9702_w19_MS_42 Q: 4

	Answer	Marks
(a)(i)	loss of energy	B1
(a)(ii)	amplitude (of oscillations) decreases (with time)	B1
(b)(i)	$\omega = 2\pi / T$	C1
	T = 0.80 s, so $\omega = 2\pi / 0.80$ ω = 7.9 rad s^{-1}	A1
(b)(ii)	$\omega^2 = 2k / M$	C1
	$7.9^2 = 2k / 1.2$ k = 37 N m^{-1}	A1
(c)(i)	(one) smooth curve, not touching the f-axis, with two concave sides meeting at a peak in between them	B1
	(one) peak at 1.0ω	B1
(c)(ii)	• lower peak/(whole) line is lower • flatter peak/peak is less sharp • peak at (slightly) lower angular frequency/peak moves to left *any two points, one mark each*	B2

111. 9702_m18_MS_42 Q: 4

	Answer	Marks
(a)	frequency at which body will vibrate when there is no (resultant external) resistive force acting on it OR frequency at which body will vibrate when there is no driving force / external force acting on it	B1
(b)(i)	resonance	B1
(b)(ii)	peak is not sharp / peak not infinite height	M1
	so damped	A1
(c)	e.g. (quartz crystal) to produce ultrasound (quartz crystal) in watch to keep timing NMR / MRI microwave ovens tuning circuits	B1

112. 9702_s18_MS_42 Q: 4

	Answer	Marks
(a)	acceleration proportional to displacement	B1
	acceleration directed towards fixed point **or** displacement and acceleration in opposite directions	B1
(b)(i)	**1.** amplitude decreases gradually so light damping **or** oscillations continue so light damping	B1
	2. loss of energy	B1
	due to friction in wheels **or** due to friction between wheels and surface (during slipping) **or** due to air resistance (on trolley)	B1
(b)(ii)1.	$\omega^2 = 2k/m$	C1
	$= (2 \times 230) / 0.950$	C1
	$\omega = 22\ \text{rad s}^{-1}$	A1
(b)(ii)2.	$T = 2\pi/\omega$	C1
	$T = (2\pi / 22) = 0.286\ \text{s}$ time $= 1.5T$ $= 0.43\ \text{s}$	A1

113. 9702_w18_MS_41 Q: 3

	Answer	Marks
(a)	$\omega^2 = 2g / L$	C1
	$T = 2\pi/\omega$	C1
	$\omega^2 = (2 \times 9.81) / 0.19$ $\omega = 10.2\ (\text{rad s}^{-1})$ $T = 2\pi / 10.2$ $= 0.62\ \text{s}$	A1
(b)(i)	e.g. viscosity of liquid/friction within the liquid/viscous drag/friction between walls of tube and liquid	B1
(b)(ii)	(maximum) KE = $\frac{1}{2}mv_0^2$ **and** $v_0 = \omega x_0$ **or** energy = $\frac{1}{2}m\omega^2 x_0^2$	C1
	change $= \frac{1}{2} \times 18 \times 10^{-3} \times 103 \times [(2.0 \times 10^{-2})^2 - (0.95 \times 10^{-2})^2]$	C1
	$= 2.9 \times 10^{-4}\ \text{J}$	A1

114. 9702_w18_MS_42 Q: 4

	Answer	Marks
4(a)	(defining equation of s.h.m. is) $a = -kx$ where k is a constant **or** $a \propto -x$	**B1**
	g and L are constant (so $a \propto -x$ and hence s.h.m.)	**B1**
(b)	$T = 0.50\,\text{s}$ **and** $T = 2\pi/\omega$	**C1**
	$\omega^2 = 2g/L$	**C1**
	$L = (2 \times 9.81 \times 0.50^2)/4\pi^2$ $= 0.12\,\text{m}$	**A1**
(c)(i)	Any one from: • viscosity of liquid • friction within the liquid • viscous drag • friction/resistance between walls of tube and liquid	**B1**
(c)(ii)	(maximum) KE = $\frac{1}{2}mv_0^2$ **and** $v_0 = \omega x_0$ **or** energy = $\frac{1}{2}m\omega^2 x_0^2$	**C1**
	ratio = $(1.3/2.0)^2$ $= 0.42$	**A1**

115. 9702_w18_MS_43 Q: 3

	Answer	Marks
(a)	$\omega^2 = 2g/L$	**C1**
	$T = 2\pi/\omega$	**C1**
	$\omega^2 = (2 \times 9.81)/0.19$ $\omega = 10.2\,(\text{rad s}^{-1})$ $T = 2\pi/10.2$ $= 0.62\,\text{s}$	**A1**
(b)(i)	e.g. viscosity of liquid/friction within the liquid/viscous drag/friction between walls of tube and liquid	**B1**
(b)(ii)	(maximum) KE = $\frac{1}{2}mv_0^2$ **and** $v_0 = \omega x_0$ **or** energy = $\frac{1}{2}m\omega^2 x_0^2$	**C1**
	change $= \frac{1}{2} \times 18 \times 10^{-3} \times 103 \times [(2.0 \times 10^{-2})^2 - (0.95 \times 10^{-2})^2]$	**C1**
	$= 2.9 \times 10^{-4}\,\text{J}$	**A1**

116. 9702_s17_MS_41 Q: 2

	Answer	Marks
(a)	e.g. period = 3 / 2.5	C1
	frequency = 0.83 Hz	A1
(b)	light (damping)	B1
(c)	at 2.7 s, A_0 = 1.5 (cm)	B1
	energy = $\frac{1}{2} m \times 4\pi^2 f^2 A_0^2$	B1
	= $\frac{1}{2} \times 0.18 \times 4\pi^2 \times 0.83^2 \times (1.5 \times 10^{-2})^2$ = 5.51×10^{-4} (J)	C1
	at 7.5 s, A_0 = 0.75 (cm)	B1
	energy = $\frac{1}{4} \times 5.51 \times 10^{-4}$ **or** energy = $\frac{1}{2} \times 0.18 \times 4\pi^2 \times 0.83^2 \times (0.75 \times 10^{-2})^2$	C1
	energy = 1.38×10^{-4} (J) change = $(5.51 \times 10^{-4} - 1.38 \times 10^{-4}) = 4.13$ J	A1

117. 9702_s17_MS_43 Q: 2

	Answer	Marks
(a)	e.g. period = 3 / 2.5	C1
	frequency = 0.83 Hz	A1
(b)	light (damping)	B1
(c)	at 2.7 s, A_0 = 1.5 (cm)	B1
	energy = $\frac{1}{2} m \times 4\pi^2 f^2 A_0^2$	B1
	= $\frac{1}{2} \times 0.18 \times 4\pi^2 \times 0.83^2 \times (1.5 \times 10^{-2})^2$ = 5.51×10^{-4} (J)	C1
	at 7.5 s, A_0 = 0.75 (cm)	B1
	energy = $\frac{1}{4} \times 5.51 \times 10^{-4}$ **or** energy = $\frac{1}{2} \times 0.18 \times 4\pi^2 \times 0.83^2 \times (0.75 \times 10^{-2})^2$	C1
	energy = 1.38×10^{-4} (J) change = $(5.51 \times 10^{-4} - 1.38 \times 10^{-4}) = 4.13$ J	A1

118. 9702_s21_MS_41 Q: 4

	Answer	Marks
	(ultrasound) pulse	B1
	reflected at boundaries	B1
	gel is used to minimise reflection at skin **or** generated and detected by quartz crystal	B1
	time delay between generation and detection gives information about depth	B1
	intensity (of reflected wave) gives information about nature of boundary	B1

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	B1	
		do not allow 'displacement constant'		
		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	A1	[3]
		for 2nd and 3rd marks, ignore the first quarter period		
		Total		[7]

Q3.

4	(a)	acceleration proportional to displacement (from a fixed point)	M1	
		or a = - $\omega^2 x$ with a, ω and x explained		
		and directed towards a fixed point	A1	[2]
		or negative sign explained		
	(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 $f = \frac{1}{2\pi}\sqrt{\frac{Apg}{M}}$	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 $= 2\pi fa$ $= 2\pi \times 40 \times 42 \times 10^{-3}$ $= 10.6\ \text{m s}^{-1}$	C1 A1	**[2]**
		(ii)	acceleration $= 4\pi^2 f^2 a$ $= (80\pi)^2 \times 42 \times 10^{-3}$ $= 2650\ \text{m s}^{-2}$	C1 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 <u>damped</u>/amplitude decreases as magnet moves, flux is cut by coil e.m.f./current is induced in the coil causing energy loss in load OR force on magnet energy is derived from oscillations of magnet OR force opposes motion of magnet	B1 B1 B1 B1 B1	[5]
		(ii)	$T = 0.60$ s $\omega_0\ (= 2\pi/T) = 10.5\ \text{rad s}^{-1}$	C1 A1	[2]
	(b)		sketch: sinusoidal wave with period unchanged or slightly smaller same initial displacement, less damping	M1 A1	[2]
	(c)	(i)	sketch: general shape – peaked curve peak at ω_0 and amplitude never zero	M1 A1	[2]
		(ii)	<u>resonance</u>	B1	[1]
		(iii)	useful: e.g. child on swing, microwave oven heating avoid: e.g. vibrating panels, vibrating bridges (*for credit, stated example must be put in context*)	B1 B1	[2]

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 T/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) reduction in amplitude / energy of oscillations due to force (always) opposing motion / resistive forces any two of the above, max 2	(B1) (B1) (B1)	[2]
		(ii)	amplitude is decreasing (very) gradually / oscillations would continue (for a long time) /many oscillations light damping	M1 A1	[2]
	(b)	(i)	frequency = 1 / 0.3 = 3.3 Hz allow points taken from time axis giving f = 3.45 Hz	A1	[1]
		(ii)	energy = ½ mv^2 and $v = \omega a$ = ½ × 0.065 × $(2\pi/0.3)^2$ × $(1.5 \times 10^{-2})^2$ = 3.2 mJ	C1 M1 A0	[2]
	(c)		amplitude reduces exponentially / does not decrease linearly so will be not be 0.7 cm	M1 A1	[2]

Q9.

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

Q10.

4	(a)	$a = (-)\omega^2 x$ and $\omega = 2\pi/T$ T = 0.60 s $a = (4\pi^2 \times 2.0 \times 10^{-2}) / (0.6)^2$ = 2.2 m s^{-2}	C1 C1 A1	[3]
	(b)	sinusoidal wave with all values positive all values positive, all peaks at E_K and energy = 0 at t = 0 period = 0.30 s	B1 B1 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 = 7.0×10^{-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 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 = $\frac{1}{2}m\omega^2x^2$ and potential energy = kinetic energy — B1
$\frac{1}{2}m\omega^2(x_0^2 - x^2) = \frac{1}{2} \times \frac{1}{2}m\omega^2x_0^2$ 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 rad s^{-1} — A1 [2]
(allow use of f = 1.5 Hz to give ω = 9.4 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 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 $\frac{1}{2}mv_0^2$ or $\frac{1}{2}m\omega^2x_0^2$
= 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
= 1.4×10^{-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 ½f_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	
			$15 \times 10^{-3} = ½ \times 0.15 \times \omega^2 \times (5.0 \times 10^{-2})^2$	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)/(5.0×10^{-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)	ω	= $2\pi f$	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	= ωx_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 ≈ 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 m s^{-1} .....(allow ± 0.1 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 and in opposite directions/directed towards fixed point	M1 A1	[2]
	(b)	energy = $\frac{1}{2}m\omega^2 x_0^2$ and $\omega = 2\pi f$ = $\frac{1}{2} \times 5.8 \times 10^{-3} \times (2\pi \times 4.5)^2 \times (3.0 \times 10^{-3})^2$ = 2.1×10^{-5} J	C1 C1 A1	[3]
	(c) (i)	at maximum displacement above rest position	M1 A1	[2]
	(ii)	acceleration = $(-)\omega^2 x_0$ and acceleration = 9.81 or g $9.81 = (2\pi \times 4.5)^2 \times x_0$ $x_0 = 1.2 \times 10^{-2}$ m	C1 A1	[2]

Q27.

4	(a)	straight line through origin shows acceleration proportional to displacement negative gradient shows acceleration and displacement in opposite directions	M1 A1 M1 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 $\omega = 2\pi f$ gradient = $13.5 / (2.8 \times 10^{-2}) = 482$ $\omega = 22$ rad s^{-1} frequency = $(22/2\pi =)$ 3.5 Hz	C1 C1 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 $\omega = 2\pi/T$	C1	
			$v = (2\pi/1.2) \times 1.5 \times 10^{-2}$	M1	
			$= 0.079\ m\ s^{-1}$	A0	[2]
			or gradient drawn clearly at a correct position	(C1)	
			working clear	(M1)	
			to give $(0.08 \pm 0.01)\ m\ s^{-1}$	(A0)	

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	(b)	(i)	sketch: curve from (±1.5, 0) passing through (0, 25) reasonable shape (*curved with both intersections between y = 12.0→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 $= \frac{1}{2}m\omega^2x_0^2$ *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 $\frac{1}{2}m\omega^2x_0^2$ and $x_0 = 0.75\,cm$ *or* x_0 is halved so ¼ energy to give new energy = 1.6 mJ C1

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)	M1	
		either acceleration and displacement in opposite directions *or* acceleration always directed towards a fixed point	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 $\frac{1}{2}\omega a = \omega\sqrt{(x_0^2 - x^2)}$ *or* $\frac{1}{2} \times 16.1 = 5.03\sqrt{(3.2^2 - x^2)}$	C1	
		$x_0^2/4 = x_0^2 - x^2$ $\quad$ $2.58 = 3.2^2 - x^2$		
		$x = 2.8\ \text{cm}$ $\quad$ $x = 2.8\ \text{cm}$	A1	[2]
	(c)	sketch: loop with origin at its centre	M1	
		correct intercepts & shape based on **(b)(ii)**	A1	[2]