Q1.

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

(b) line: amplitude less at all frequencies \( \ldots \) \( B1 \)
peak flatter \( \ldots \) \( B1 \)
peak at \( f_0 \) or slightly below \( f_0 \) \( \ldots \) \( B1 \)

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

Q2.

4 (a) e.g. amplitude is not constant or wave is damped \( \ldots \) \( B1 \)
do not allow 'displacement constant' should be (-)cos, (not sin) \( B1 \) \( [2] \)

(b) \( T = 0.60 \text{ s} \)
\( \omega = 2\pi / T = 10.5 \text{ rad s}^{-1} \) (allow 10.4 \( \rightarrow \) 10.6) \( A1 \) \( [2] \)

(c) same period \( \ldots \) \( B1 \)
displacement always less \( \ldots \) \( B1 \)
amplitude reducing appropriately \( \ldots \) \( M1 \)
for 2\(^{nd}\) and 3\(^{rd}\) marks, ignore the first quarter period \( \ldots \) \( A1 \)

Total \( [7] \)

Q3.

4 (a) acceleration proportional to displacement (from a fixed point) \( \ldots \) \( M1 \)
\( \text{or } a = - \omega^2 x \) with \( a, \omega \) and \( x \) explained \( \ldots \) \( A1 \) \( [2] \)
and directed towards a fixed point \( \ldots \) \( \text{or negative sign explained} \)

(b) for s.h.m., \( a = (-) \omega^2 x \)
identifies \( \omega^2 \) as \( A_p g / M \) and therefore s.h.m. (may be implied) \( \ldots \) \( B1 \)
\( 2\pi f = \omega \) \( \ldots \) \( B1 \)
hence \( f = \frac{1}{2\pi} \sqrt{\frac{A_p g}{M}} \) \( \ldots \) \( A0 \) \( [3] \)

(c) (i) \( T = 0.60 \text{ s} \) or \( f = 1.7 \text{ Hz} \)
\( 0.60 = \frac{(2\pi)^2}{M} \sqrt{(\pi \times (1.2 \times 10^2)^2 \times 950 \times 9.81)} \)
\( M = 0.0384 \text{ kg} \) \( \ldots \) \( C1 \)

(ii) \( \text{decreasing peak height/amplitude} \) \( \ldots \) \( B1 \) \( [1] \)
Q4.

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

Q5.

7
(a) (i) oscillations are damped/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
(ii) \(T = 0.60 \text{ s}\)
\(\omega_b (= 2\pi/T) = 10.5 \text{ rad s}^{-1}\)
(b) sketch: sinusoidal wave with period unchanged or slightly smaller
same initial displacement, less damping
(c) (i) sketch: general shape – peaked curve
peak at \(\omega_b\) and amplitude never zero
(ii) resonance
(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)

Q6.
3  (a) (i) amplitude = 0.5 cm  \hspace{1cm} A1 [1]
   (ii) period = 0.8 s  \hspace{1cm} A1 [1]

(b) (i)  \[ \omega = \frac{2\pi}{T} \]
        \[ = 7.85 \text{ rad s}^{-1} \]
        \[ \text{correct use of } v = \omega \sqrt{x_0^2 - x^2} \]
        \[ = 7.85 \times \sqrt{(0.5 \times 1 \times 10^{-2})^2 - (0.2 \times 1 \times 10^{-2})^2} \]
        \[ = 3.6 \text{ cm s}^{-1} \]
        \[ \text{(if tangent drawn or clearly implied } \text{B1}) \]
        \[ 3.6 \pm 0.3 \text{ cm s}^{-1} \]
        \[ \text{but allow } 1 \text{ mark for } > \pm 0.3 \text{ but } \leq \pm 0.6 \text{ cm s}^{-1} \]  \hspace{1cm} A1 [3]
   (ii)  \[ d = 15.8 \text{ cm} \]  \hspace{1cm} A1 [1]

(c) (i) (continuous) loss of energy / reduction in amplitude (from the oscillating system)
      caused by force acting in opposite direction to the motion / friction / viscous forces  \hspace{1cm} B1
   (ii) same period / small increase in period
      line displacement always less than that on Fig.3.2 (ignore first 1/4)
      peak progressively smaller  \hspace{1cm} B1 [2]

Q7.

3  (a) (i) to-and-fro / backward and forward motion (between two limits)  \hspace{1cm} B1 [1]
   (ii) no energy loss or gain / no external force acting / constant energy / constant amplitude  \hspace{1cm} B1 [1]
   (iii) acceleration directed towards a fixed point
      acceleration proportional to distance from the fixed point / displacement  \hspace{1cm} B1 [2]

(b) acceleration is constant (magnitude)
      so cannot be s.h.m.  \hspace{1cm} M1

Q8.
Q9.

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 = \( \frac{1}{2} mv^2 \) and  

    \( v = \omega a \)  
    = \( \frac{1}{2} \times 0.085 \times (2\pi/0.3)^2 \times (1.5 \times 10^{-2})^2 \)  
    = 3.2 mJ  
    C1  
    M1  
    A0 [2]

(c) amplitude reduces exponentially / does not decrease linearly  
    so will 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) \( A\dot{g} / m \) is a constant and so acceleration proportional to x  
    negative sign shows acceleration towards a fixed point / in opposite  
    direction to displacement  
    B1  

    (ii) \( \omega^2 = (A\dot{g} / m) \)  

    \( \omega = 2\pi f \)  
    \( (2 \pi \times 1.5 \pi)^2 = ((4.5 \times 10^{-4} \times 1.0 \times 10^3 \times 9.81) / m) \)  
    C1  
    C1  
    C1  

Q10.

4 (a) \( a = (-)\omega^2 x \) and \( \omega = 2\pi / T \)  

    \( T = 0.60 \text{s} \)  
    C1  

    \( a = (4\pi^2 \times 2.0 \times 10^{-2}) / (0.6)^2 \)  
    \( = 2.2 \text{m/s}^2 \)  
    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 [3]

Q11.
Q12.

(a) energy \(= \frac{1}{2} m \omega^2 a^2\) and \(\omega = 2\pi f\)
\[= \frac{1}{2} \times 37 \times 10^{-3} \times (2\pi \times 3.5)^2 \times (2.8 \times 10^{-2})^2\]
\[= 7.0 \times 10^{-3} \text{J}\]  
(allow \(2\pi \times 3.5\) shown as \(7\pi\))

Energy = \(\frac{1}{2}mv^2\) and \(v = r\omega\)
Correct substitution
Energy = \(7.0 \times 10^{-3}\) J

(b) \(E_K = E_P\)
\[\frac{1}{2}m\omega^2 (a^2 - x^2) = \frac{1}{2}m\omega^2 x^2\] or \(E_K = 3.5\) mJ
\(x = a/\sqrt{2} = 2.8/\sqrt{2}\) or \(E_K = \frac{1}{2}m\omega^2 (a^2 - x^2)\) or \(E_P = \frac{1}{2}m\omega^2 x^2\)

\(= 2.0\) cm
\((E_K = E_P = 7.0\) mJ scores 0/3\)

Allow:
\(k = 17.9\)
\(E = \frac{1}{2}kx^2\)
\(x = 2.0\) cm

(c) (i) graph: horizontal line, y-intercept = \(7.0\) mJ with end-points of line at +2.8 cm and -2.8 cm

(ii) graph: reasonable curve with maximum at (0, 7.0) end-points of line at (-2.8, 0) and (+2.8, 0)

(iii) graph: inverted version of (ii) with intersections at (-2.0, 3.5) and (+2.0, 3.5)
(Allow marks in (iii), but not in (ii), if graphs K & P are not labelled)

(d) gravitational potential energy
3 (a) (i) 1. amplitude = 1.7 cm
   period = 0.36 cm
   frequency = 1/0.36
   = 2.8 Hz

   (ii) \( a = (-)z^2 x \) and \( \omega = 2\pi / T \)
   acceleration = \((2\pi / 0.36)^2 \times 1.7 \times 10^{-2}\)
   = 5.2 m/s²

(b) graph: straight line, through origin, with negative gradient
   from \((-1.7 \times 10^{-2}, 5.2)\) to \((1.7 \times 10^{-2}, -5.2)\)
   (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 = \( \frac{1}{2} m \omega^2 \dot{x}^2 \)
    and potential energy = kinetic energy
    \( \frac{1}{2} m \omega^2 (x_0^2 - x^2) = \frac{1}{2} \times \frac{1}{2} m \omega^2 x_0^2 \)
    or \( \frac{1}{2} m \omega^2 \dot{x}^2 = \frac{1}{2} \times \frac{1}{2} m \omega^2 x_0^2 \)
    \( x_0^2 = 2\dot{x}^2 \)
    \( x = x_0 / \sqrt{2} = 1.7 / \sqrt{2} \)
    = 1.2 cm

Q13.

3 (a) (i) \( \omega = \frac{2\pi}{T} \)
    = \( 2\pi / 0.69 \)
    = 9.1 rad s⁻¹
    (allow use of \( f = 1.5 \) Hz to give \( \omega = 9.4 \) rad s⁻¹)

(ii) 1. \( x = 2.1 \cos 9.1t \)
    2.1 and 9.1 numerical values
    use of cos

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
   \( v = v_0 \sin 9.1t \) (allow cos 9.1t if sin used in (ii)1.)

(b) energy = either \( \frac{1}{2} mv_0^2 \) or \( \frac{1}{2} m \omega^2 x_0^2 \)
   = either \( \frac{1}{2} \times 0.078 \times 0.19^2 \) or \( \frac{1}{2} \times 0.078 \times 9.1^2 \times (2.1 \times 10^{-2})^2 \)
   = 1.4 \times 10^{-3} J

Q14.
3 (a) (i) constant amplitude ......................................................... B1
(ii) period = 0.75 s ...(allow ±0.2 s)........................................... C1
\[ \omega = 2\pi/T \] ................................................................. C1
\[ \omega = 8.4 \text{ rad s}^{-1} \] ...(±1 for 1 sf).............................. A1
(iii) either use of gradient or \( v = \omega y_0 \) .................................. C1
\[ v = 0.168 \text{ m s}^{-1} \] ................................................... 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) \( a, \omega \) 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
\[ (2\pi)^2 = (2 \times 120)/0.90 \] ......................................... C1
\[ f = 2.6 \text{ Hz} \] ........................................................... 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.
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
\( \omega = \sqrt{2k/m} \) or \( \omega^2 = (2k/m) \)
\( \omega = 2\pi f \)
\( f = (1/2\pi)\sqrt{(2 \times 300)/0.2400} \)
= 7.96 \approx 8 Hz ....................................................................... B1 [1]

(b)(i) resonance .............................................................................. B1 [1]

(ii) 8 Hz .................................................................................... B1 [1]

(c) (increase amount of) damping ..................................................... B1
without altering \((k \text{ or } m) \) ... (some indirect reference is acceptable)
sensible suggestion .................................................................. B1 [3]

Q19.
Q20.

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

(ii) (max.) kinetic energy = 2.56 mJ ........................................... C1

\[ v_{\text{max}} = \sqrt{\frac{2}{m} \times 2.56 \times 10^{-3}} \]

\[ = \sqrt{\frac{2}{m} \times 0.130 \times (0.8 \times 10^{-3})^2} \]

\[ \frac{2.56 \times 10^{-3}}{2} \times 0.130 \times (0.8 \times 10^{-3})^2 \]

\[ = 2.56 \times 10^{-3} \times 0.130 \times (0.8 \times 10^{-3})^2 \]

\[ = 4.0 \text{ Hz (3.95 Hz)} \] ......................................................... A0 [6]

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

(ii) 1.40 Hz ............................................................... B1

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

Q21.

3  (a) acceleration / force (directly) proportional to displacement

and either directed towards fixed point

or acceleration & displacement in opposite directions

M1

A1 [2]

(b) (i) maximum / minimum height / 8 mm above cloth / 14 mm below cloth

B1 [1]

(ii) 1. \( a = 11 \text{ mm} \)

2. \( \omega = 2\pi f \)

\[ = 2\pi \times 4.5 \]

\[ = 28.3 \text{ rad s}^{-1} \] (do not allow 1 s.f.)

A1 [2]

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**GCE A/AS LEVEL – October/November 2008**

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</table>
| (c) (i) | \( v = \omega \sqrt{a^2 - y^2} \)

\[ = 28.3 \times 10^{-3} \times 11 \times 10^{-3} \]

\[ = 0.31 \text{ m s}^{-1} \] (do not allow 1 s.f.)

A1 [2]

(ii) \( v = \omega \sqrt{(a^2 - y^2)} \)

\[ y = 3 \text{ mm} \]

\[ = 28.3 \times 10^{-3} \sqrt{(11^2 - 3^2)} \]

\[ = 0.30 \text{ m s}^{-1} \] (allow 1 s.f.)

C1

A1 [3]
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
    \[ f = 250 \text{ Hz} \] .........................................................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.
Q24.

3 (a) (i) resonance  

(ii) amplitude 16 mm and frequency 4.6 Hz

(b) (i) \( a = (-) \omega^2 x \) and \( \omega = 2\pi f \)
\[ a = 4\pi^2 \times 4.6^2 \times 16 \times 10^{-3} \]
\[ = 13.4 \text{ m/s}^2 \]

(ii) \( F = ma \)
\[ = 150 \times 10^{-3} \times 13.4 \]
\[ = 2.0 \text{ N} \]

(c) line always ‘below’ given line and never zero peak is at 4.6 Hz (or slightly less) and flatter

M1

Q25.

3 (a) (i) amplitude remains constant  

(ii) amplitude decreases gradually light damping

(iii) period = 0.80 s  
frequency = 1.25 Hz (period not 0.8 s, then 0/2)

Q26.
3 (a) acceleration proportional to displacement/distance from fixed point and in opposite directions/directed towards fixed point

\[ \text{energy} = \frac{1}{2}m\omega^2 x_0^2 \text{ and } \omega = 2\pi f \]
\[ = \frac{1}{2} \times 5.8 \times 10^{-3} \times (2\pi \times 4.5)^2 \times (3.0 \times 10^{-3})^2 \]
\[ = 2.1 \times 10^{-5} \text{ J} \]

(c) (i) at maximum displacement above rest position

(ii) acceleration = \( (-\omega^2)x_0 \) and acceleration = 9.81 or \( g \)
\[ 9.81 = (2\pi \times 4.5)^2 \times x_0 \]
\[ x_0 = 1.2 \times 10^{-2} \text{ m} \]

Q27.

4 (a) straight line through origin shows acceleration proportional to displacement negative gradient shows acceleration and displacement in opposite directions

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<td>9702</td>
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<tr>
<td>(b)</td>
<td>A1</td>
</tr>
<tr>
<td>(i)</td>
<td>2.8 cm</td>
</tr>
<tr>
<td>(ii)</td>
<td>( \text{either gradient} = \omega^2 \text{ and } \omega = 2\pi f \text{ or } a = -\omega^2 x \text{ and } \omega = 2\pi f )</td>
</tr>
<tr>
<td></td>
<td>gradient = 13.5/(2.8 \times 10^{-3}) = 482</td>
</tr>
<tr>
<td></td>
<td>( \omega = 22 \text{ rad s}^{-1} )</td>
</tr>
<tr>
<td></td>
<td>frequency = (22/2\pi) = 3.5 \text{ Hz}</td>
</tr>
<tr>
<td>(c)</td>
<td>e.g. lower spring may not be extended e.g. upper spring may exceed limit of proportionality/elastic limit (any sensible suggestion)</td>
</tr>
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</table>

Q28.
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 \( \omega = \frac{2\pi}{T} \)
    \[ v = (2\pi 1.2) \times 1.5 \times 10^{-2} \]
    \[ = 0.079 \text{ m s}^{-1} \]
    or gradient drawn clearly at a correct position
    working clear
    to give \((0.08 \pm 0.01) \text{ m s}^{-1}\)  
    C1
    M1
    A0 [2]

(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]

Q30.

(b) (i) sketch: curve 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 [2]
Q31.

4 (a) kinetic (energy) $KE/E_k$

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

Q32.

1 (a) (i) either $\omega = 2\pi / T$ or $\omega = 2\pi$ and $f = 1 / T$
\[ \omega = \frac{2\pi}{0.30} = 20.9 \text{ rad s}^{-1} \text{ (accept 2 s.f.)} \]
(ii) kinetic energy = $\frac{1}{2} m \omega^2 x_0^2$ or $v = \omega x_0$ and $\frac{1}{2}mv^2$
\[ = \frac{1}{2} \times 0.130 \times 20.9^2 \times (1.5 \times 10^{-3})^2 = 6.4 \times 10^{-3} \text{ J} \]

(b) (i) as magnet moves, flux is cut by cup/aluminium giving rise to induced e.m.f. (in cup)
induced e.m.f. gives rise to currents and heating of the cup
thermal energy derived from oscillations of magnet so amplitude decreases
induced e.m.f. gives rise to currents which generate a magnetic field
the magnetic field opposes the motion of the magnet so amplitude decreases

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

(c) $q = mc \Delta \theta$
\[ 4.8 \times 10^{-3} = 6.2 \times 10^{-3} \times 910 \times \Delta \theta \]
\[ \Delta \theta = 8.5 \times 10^{-4} \text{ K} \]
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  
   
   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. \( \omega = \frac{2\pi}{T} \) and \( v_0 = \omega x_0 \)  
      \( \omega = \frac{2\pi}{1.25} \)  
      = 5.03 rad s\(^{-1}\)  
      C1  

      \( v_0 = 5.03 \times 3.2 \)  
      = 16.1 cm s\(^{-1}\) (allow 2 s.f.)  
      A1  [3]

2. \( v = \omega \sqrt{x_0^2 - x^2} \)  
   either \( \frac{1}{2} \omega x = \omega \sqrt{x_0^2 - x^2} \) or \( \frac{1}{2} \times 16.1 = 5.03 \sqrt{3.2^2 - x^2} \)  
   x\(^2\)/4 = x_0^2 - x^2  
   2.58 = 3.2^2 - x^2  
   x = 2.8 cm  
   A1  [2]

(c) sketch: loop with origin at its centre 
   correct intercepts & shape based on (b)(ii)  
   M1  
   A1  [2]