# Marking Scheme

#1

| Question | | | Marking details | Marks Available |
|---|---|---|---|---|
| 5 | *(a)* | | $\omega = \frac{2\pi(1200)}{60}$ (conversion of units (1)) $= 125.7$ [rad s$^{-1}$] (1)<br><br>$F = m\omega^2 r = (0.80)(125.7)^2(0.25)$(subs (1)) $= 3160.1$ [N] (1) | 4 |
| | *(b)* | (i) | $R - mg = 3\ 160.1$ (1)<br><br>$R = 3\ 160.1 + (0.8)(9.81) = 3\ 168$ [N] (1) **ecf** from (a) | |
| | | (ii) | $R + mg = 3\ 160.1$<br><br>$R = 3\ 160.1 - (0.8)(9.81) = 3\ 152$ [N] (1) **ecf** from (a) | 3 |
| | *(c)* | | Resonance – frequency of rotation matches the natural / resonant frequency of vibration of the saucepan [lid] (1)<br><br>[When the spin rate decreases,] the frequencies no longer match / so no resonance (1) | 2 |
| | | | **Question 5 Total** | **[9]** |

#2

| Question | | | Marking details | Marks available | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | AO1 | AO2 | AO3 | Total | Maths | Prac |
| 1 | *(a)* | (i) | Velocity [of car] is changing [with time] (1)<br>because its direction is changing [so the car is accelerating] (1)<br>or<br>There is a resultant force (1)<br>[towards the centre] due to friction / grip (1) | 2 | | | 2 | | |
| | | (ii) | $v = \frac{45\times10^3}{60\times60} = 12.5$ m s$^{-1}$ (conversion) (1)<br>$\omega = \frac{v}{r} = \frac{12.5}{80} = 0.156$ rad s$^{-1}$ substitution and calculation (1) | | 2 | | 2 | 2 | |
| | | (iii) | $a = \frac{v^2}{r} = \frac{(12.5)^2}{80}$ substitution (ecf) (1) [Alt: use $a=\omega^2 r$]<br>$= 1.95$ m s$^{-2}$ (1)<br>Direction: towards centre (of 'circular' motion) (1) | 1<br>1 | 1 | | 3 | 2 | |
| | *(b)* | | Either: Any two × (1) of these points<br>- Appropriate tyre design for friction<br>- Banking of road [for contribution from normal contact force]<br>- Appropriate surface<br>- Suspension set-up<br>- Anti-roll bars.<br>(or any sensible answers, one referring to road and the other to the car)<br><br>Or any one sensible point (1) + explanation of the role of physics (1) [ | | | 2 | 2 | | |
| | | | **Question 1 total** | 4 | 3 | 2 | 9 | 4 | 0 |

#3

| Question | | | Marking details | AO1 | AO2 | AO3 | Total | Maths | Prac |
|---|---|---|---|---|---|---|---|---|---|
| | | | | **Marks available** | | | | | |
| (a) | (i) | | $T$ tension in the string **and** $mg$ weight of mass (gravitational force or gravity) | 1 | | | 1 | | |
| | (ii) | | $T$ does not have a component tangential to the arc (1)<br>Component of $mg$ tangential to the arc is $mg\ \sin\theta$, (1) this is in the opposite direction to $s$ (or $\theta$) **and** so the negative sign (1) | | 3 | | 3 | 1 | |
| | (iii) | | $\text{acceleration} = \frac{-mg\sin\theta}{m} = -g\ \sin\theta$<br>$= -g\theta\ (1)(\text{using the approximation})$<br>$\theta = \frac{s}{l}\ \text{or}\ \sin\theta = \frac{s}{l}(1) = -\frac{gs}{l}$ | | 2 | | 2 | 2 | |
| | (iv) | | Acceleration $\propto\ \theta$ (or $s$) measured [from a fixed position] (1)<br>and opposite in direction (-ve) so SHM (1) | | | 2 | 2 | | |
| (b) | (i) | I | Substitution: $T = 2\pi\sqrt{\frac{l}{g}} = 2\pi\sqrt{\frac{1.2}{9.81}}$ (1)<br>$= 2.20$ [s] (1) | 1 | 1 | | 2 | 2 | |
| | | II | $f = \frac{1}{T} = 0.45[5]$ [H]z **ecf** (1) | | 1 | | 1 | 1 | |
| | (ii) | | For maximum distance along the arc $\theta_{\max} = 0.067$,<br>also $\sin\theta_{\max} = 0.067$<br>As $\theta_{\max} = \sin\theta_{\max}$ (i.e. for the largest value of $\theta$) (1)<br>then $\sin\theta$ is equal to $\theta$ for all $\theta$, and approximation holds for SHM.<br>System oscillates with SHM (1) | | | 2 | 2 | 1 | |
| | | | **Question total** | **2** | **7** | **4** | **13** | **7** | **0** |

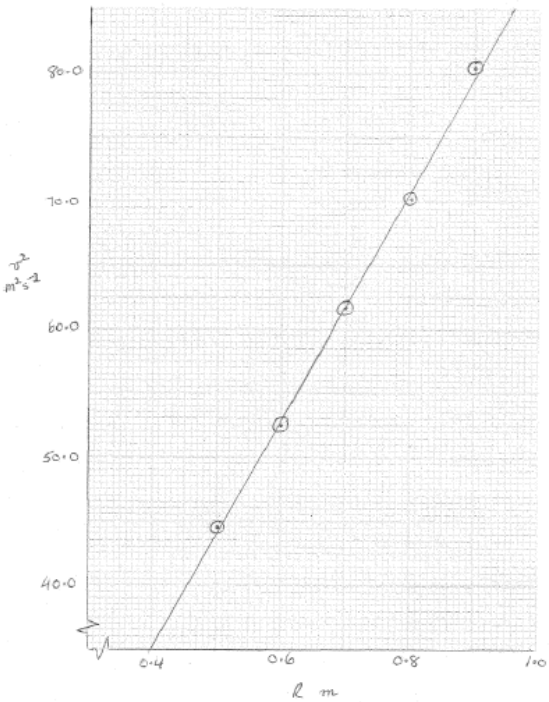
#4

| Question | | | Marking details | AO1 | AO2 | AO3 | Total | Maths | Prac |
|---|---|---|---|---|---|---|---|---|---|
| | | | | **Marks available** | | | | | |
| 2 | *(a)* | | Angle when arc [length] equals radius<br>Accept about 57.3° **or** angle when $2\pi$ = 360° or cycle / circle | 1 | | | 1 | | |
| | *(b)* | (i) | Use of $T = \frac{1}{f}$ (1)<br>Answer = 1.67 [s] (1) Accept $\frac{5}{3}$ **or** 1.66 **or** $1.\dot{6}$ **or** 1.7 [s]<br>Don't accept 1.6 [s] | 1 | 1 | | 2 | 1 | |
| | | (ii) | Substitution into $\omega = \frac{2\pi}{T}$ or $2\pi f$ or **and** $v = \omega r$ (1) **ecf** on $T$ or $f$<br>$v$ = 10.6 [m s$^{-1}$] (1)<br>(Accept 10.5 m s$^{-1}$ if 1.67 s used) | | 2 | | 2 | 2 | |
| | *(c)* | | $N = \frac{mv^2}{r}$ or $mr\omega^2$ or implied (1)<br>$N = \frac{66.2\times(10.6)^2}{2.8}$ = [2 634] [N] (1) **ecf** on $v$ and $\omega$ accept approximately 2 657 [N]<br>$F$ = 66.2 × 9.81 = [649.4 [N]] (1)<br>Vertical forces are balanced or equivalent e.g. $F = W$ (1) | 1<br>1 | 1<br>1 | | 4 | 2 | |
| | *(d)* | (i) | 650 ≤ **or** = **or** < $\mu$ × 2 600 (1)<br>So $\mu >$ **or** = 0.24 or 0.25 (1)<br>**Alternative:**<br>2 600 × 0.25 (1)<br>= 650 (1) | 1 | 1 | | 2 | 2 | |
| | | (ii) | Friction = 650 [N] or implied (1)<br>$\frac{650}{0.45}$ = 1 444 [N] (1)<br>Equating to centripetal (1)<br>$\omega$ = 2.8 [rad s$^{-1}$] (1)<br>Answer of 2.51 [rad s$^{-1}$] award 1 mark only | | 1 | 1<br>1<br>1 | 4 | 2 | |
| | | | **Question 2 total** | **5** | **7** | **3** | **15** | **9** | **0** |

#5

| | | | |
|---|---|---|---|
| *(a)* | (i) | $\omega = \frac{45(2\pi)}{60} = 4.71$ [rad s$^{-1}$]<br>Conversion from rotations to radians, with the '45'. (1)<br>Conversion from minutes to seconds and convincing working. (1) | 2 |
| | (ii) | $velocity = \omega r = (4.71)(0.08) = 0.38$ [m s$^{-1}$]<br>Formula and substitution. (1)<br>Result. (1) | 2 |
| | (iii) | $acceleration = \omega^2 r = (4.71)^2(0.08) = 1.77$ [m s$^{-2}$]<br>Formula and substitution. (1)<br>Result (1) | 2 |
| | (iv) | Towards point Q, or towards centre of circle. | 1 |
| *(b)* | (i) | $A = 0.080$ [m] | 1 |
| | (ii) | $T = \frac{2\pi}{\omega} = \frac{2\pi}{4.71} = 1.33$[s] | 1 |
| | (iii) | $a = -1.77\sin(4.71 \times 0.20) = -1.43$ [m s$^{-2}$]<br>Substitution of time (1).<br>Result with minus sign (1) | 2 |
| | (iv) | A body moves with SHM if its acceleration<br>- is directly proportional to its displacement from a fixed point<br>- is always directed towards that [fixed] point<br>1 for: each statement | 2 |
| | (v) | $a = -\omega^2 A\sin(\omega t)$;<br>$x = A\sin\omega t$ so substitution gives:<br>$a = -\omega^2 x$<br>convincing manipulation. (1)<br>final expression linking to SHM.(1) | 2 |
| *(c)* | | $x = 0.06\sin\left(4.71t - \frac{\pi}{2}\right)$.<br>1 for: each correct parameter inserted. | 3 |

#6

<table>
<tr><th colspan="3" rowspan="2">Question</th><th rowspan="2">Marking details</th><th colspan="4">Marks available</th><th></th><th></th></tr>
<tr><th>AO1</th><th>AO2</th><th>AO3</th><th>Total</th><th>Maths</th><th>Prac</th></tr>
<tr><td></td><td>(a)</td><td></td><td>Distance moved by mass P in 1 period, $T$ (i.e. in one rotation) = <br>$2\pi R$ and speed = distance / time = $\frac{2\pi R}{T}$<br>Alternative:<br>$\omega = \frac{2\pi}{T}$ and $v = \omega R$</td><td></td><td>1</td><td></td><td>1</td><td>1</td><td>1</td></tr>
<tr><td></td><td>(b)</td><td></td><td><table>
<tr><th>$R$ /m</th><th>Time of 10 rot /s</th><th>$T$ /s</th><th>$v$ / m s$^{-1}$</th><th>$v^2$ / m$^2$ s$^{-2}$</th></tr>
<tr><td>0.50</td><td>4.7</td><td>0.47</td><td>6.68</td><td>44.6</td></tr>
<tr><td>0.60</td><td>5.2</td><td>0.52</td><td>7.25</td><td>52.6</td></tr>
<tr><td>0.70</td><td>5.6</td><td>0.56</td><td>7.85</td><td>61.6</td></tr>
<tr><td>0.80</td><td>6.0</td><td>0.60</td><td>8.38</td><td>70.2</td></tr>
<tr><td>0.90</td><td>6.3</td><td>0.63</td><td>8.98</td><td>80.6</td></tr>
</table>
$T$ column: All values correct (1)<br>For column $v$ all values correct (1)<br>For column $v^2$ all values correct ecf (1)<br>Consistent use of sig figs in each column and 2 or 3 sig figs (1)</td><td></td><td>4</td><td></td><td>4</td><td>4</td><td>4</td></tr>
<tr><td></td><td>(c)</td><td>(i)</td><td>Centripetal force = $0.010\frac{v^2}{R}$<br>(1 for $\frac{mv^2}{R}$; 1 if value inserted for $m$)</td><td>1</td><td>1</td><td></td><td>2</td><td>1</td><td>2</td></tr>
<tr><td></td><td></td><td>(ii)</td><td>Forces acting on mass Q: $0.090\,g - \tau = 0$   $\tau$: tension (1)<br>So $\tau = 0.090g$. Substitution for $\tau$ into (c)(i) (1)<br>$0.090g = 0.010\frac{v^2}{R}$<br>$v^2 = \frac{0.090g}{0.010}R$<br>$v^2 = 9g\ R$ clear and convincing working (1)</td><td></td><td>3</td><td></td><td>3</td><td>2</td><td>3</td></tr>
<tr><td></td><td>(d)</td><td>(i)</td><td>

Axes, suitable choice scales (no multiples of 3) and labels on both axes (1) – scales to occupy more than half of paper<br>All points plotted correctly to ±½ small square division (2)<br>4 points plotted correctly to ±½ small square division award 1 mark<br>1-3 points plotted correctly to ±½ small square division award 0 marks<br>Line of best fit (1)</td><td></td><td>4</td><td></td><td>4</td><td>4</td><td>4</td></tr>
<tr><td></td><td></td><td>(ii)</td><td>gradient = $\frac{50.0}{0.56}$ = 89.286 m s$^{-2}$ ; find gradient from best fit line (1)<br>also gradient = $9g$ general method (1)<br>$9g = 89.286$<br>$g = \frac{1}{9}89.286 = 9.92$ m s$^{-2}$ unit mark (1)</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | $g = \frac{\ }{9}\,89.286 = 9.92$ m s$^{-2}$ **unit mark** (1)<br>(Accept $g$ = 8.8 to 10.8 m s$^{-2}$ i.e. uncertainty of ~10%.)<br>Use of single data point award a maximum of 2 marks | | | 3 | 3 | 3 | 3 |
| | | (iii) | Take measurements for each value of $R$ several times **or** measure time of more rotations **or** use of video capture or increase radius and period<br>Accept repeat readings<br>Don't accept have an assistant | | | 1 | 1 | | 1 |
| | | | **Question total** | **1** | **13** | **4** | **18** | **15** | **18** |

#7

| | | | |
|---|---|---|---|
| *(a)* | | [centripetal force =] $m\omega^2 r$ [or $\omega^2 r$ and $ma$] (1)<br>$F = 32.5 \times 1.4^2 r$ [= 63.7 $r$] (1)<br>Friction [of the surface on the shoes] provides centripetal force [or is the resultant etc.] (1) [Accept $F = m\omega r^2$ for 1st and 3rd marks as $F$ is defined in the question] | 3 |
| *(b)* | | 63.7 $r$ = 114 [N] (1)<br>$r$ = 1.79 **and** relevant comment, e.g. if $r$ greater, $F$ > 114 N (1)<br>[Alt: Subst $r$ = 1.8 m and comment that F > 114 N] | 2 |
| *(c)* | | $T = \frac{2\pi}{\omega}$ [or by impl.] (1) $= [\frac{2\pi}{1.4} =]$ 4.49 s (1) | 2 |
| *(d)* | | $v = \omega A$ [or by impl.] (1) = [1.4 × 1.8 = ] 2.52 m s$^{-1}$ (1)<br>[If $v = A\omega \cos \omega t$, or equiv, then $\cos \omega t = 1$ must be stated for 1st mark] | 2 |
| *(e)* | | $a = \omega^2 A$ [or by impl.] (1) = [1.4$^2$ × 1.8 =] 3.53 m s$^{-2}$ (1)<br>occurs at the extremities / when $x = \pm A$ etc. (1)<br>[If $a = A\omega^2 \cos \omega t$, or equiv, then $\cos \omega t = 1$ must be stated for 1st mark] | 3 |
| *(f)* | | At least one cycle of wave drawn with correct amplitude [1.8 m e.c.f.] (1)<br>Reasonable shape of sinusoid + correct period + correct phase [i.e. sin wave] (1) | 2 |
| *(g)* | | Use of – 1.00 = sin $\omega t$ (1)<br>$1.4t = \sin^{-1}\left(\frac{-1}{1.8}\right)$ (1) [= – 0.59]<br>$t$ = – 0.42 s (1)<br>[Mysterious loss of – sign loses 1 mark]<br>$t_1 = \frac{T}{2} + 0.42$ [2.42 s] **and** $t_2 = T - 0.42$ [4.07 s] (1)<br>Max 2 marks for reading from graph ± 0.1 s, i.e 2.6, 2.7 s ✓ 4.0, 4.1 s ✓ | 4 |
| | | | [18] |

#8

| Question | | | Marking details | AO1 | AO2 | AO3 | Total | Maths | Prac |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Marks available | | | | | |
| | (a) | (i) | Use of the equation $\frac{M_2 d}{(M_1 + M_2)} = x$ even if wrong $M_2$ (1)<br>$\frac{9.2\times10^{24}\times5.3\times10^{10}}{\{9.5\times10^{29}+\{9.2\times10^{24}\}\}}$ seen (1)<br>( $\{+9.2\times10^{24}\}$ can be omitted from the above equation)<br>**or** 513 263 [m] seen etc. | 1<br>1 | | | 2 | 2 | |
| | | (ii) | $v = \frac{2\pi r}{T}$ applied or $v = \omega r$ and $\omega = \frac{2\pi}{T}$ combined (1)<br>Conversion of 130 days (130 × 24 × 3 600) (1)<br>Answer = 0.287 [m $s^{-1}$] (**ecf** on day conversion) (1) | 1 | 1<br>1 | | 3 | 3 | |
| | | (iii) | Redshift is small **or** the redshift is proportional to velocity **or** small $\Delta\lambda$ **or** shown using the Doppler equation (1)<br>Small wavelength change is difficult to measure **or** shifted wavelength is too close to the original (1) | | 2 | | 2 | | |
| | (b) | (i) | $F = \frac{GMm}{r^2}$ used (1)<br>Answer = $2.08\times10^{23}$ [N] (1) | 1 | 1 | | 2 | 2 | |
| | | (ii) | Method for obtaining stress i.e. $\frac{F}{A}$ (1)<br>$1.35\times10^{9}$ [Pa] (1)<br>Correct conclusion e.g. the steel bar would break **ecf** (1)<br>Theory doesn't work / Newton's grav law used successfully for centuries / won't work for elliptical orbits / would melt (1)<br>**Alternative:**<br>Use of $F = \sigma A$ (1)<br>$F = 6.9\times10^{22}$ [N] (1) | | | 4 | 4 | 2 | |
| | (c) | (i) | $\text{PE} = -\frac{GMm}{r}$ used N.B. **ecf** if PE = $Fr$ used (1)<br>Answer = [-]$1.10\times10^{34}$ [J] (1) | 1 | 1 | | 2 | 2 | |
| | | (ii) | Realising KE is involved (1)<br>Correct variation with distance for KE or velocity **or** as PE increases KE decreases or converse (1) | | | 2 | 2 | | |
| | | | **Question total** | **5** | **6** | **6** | **17** | **11** | **0** |