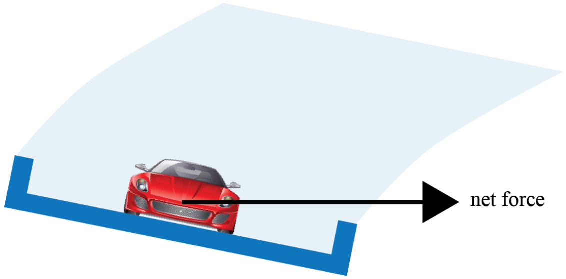
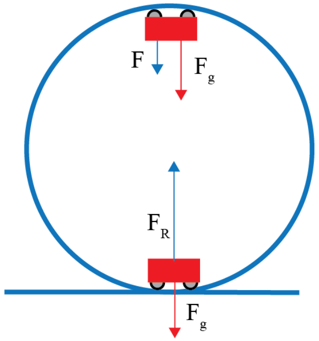
Assessment Schedule – 2023

Physics: Demonstrate understanding of mechanical systems (91524)

Evidence

Q	Evidence	Achievement	Merit	Excellence
ONE (a)	Horizontal component of the reaction force pointing towards centre of circle.  	• Correct answer on diagram provided. (Accept F_c, F_{net} or $F_{r\,hoz}$ as label.) OR Appropriate vector diagram with appropriate orientation.	•	
(b)	$F_c = \frac{mv^2}{r}$ and $F_g = mg$ Therefore, using the vector diagram: $\theta = \tan^{-1}\left(\frac{F_c}{F_g}\right)$ $\theta = \tan^{-1}\left(\frac{0.3844}{1.1772}\right)$ OR $F_c = \frac{mv^2}{r} = F_R \sin\theta$ $F_g = mg = F_R \cos\theta$ $v^2 = rg\tan\theta$ $\theta = \tan^{-1}\left(\frac{1.55^2}{0.750 \times 9.81}\right) = 18.1°$ Accept other reasonable methods of solving this.	• One error in calculation. (e.g. incorrect trig function). OR Correct vector diagram. OR Both F_c and F_g calculated correctly.	• Correct answer.	

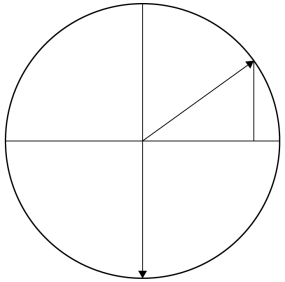
(c)	 The feeling of weight depends on the size of the reaction force. At the bottom of the loop, **F_R must be greater than Fg** to provide the Fc. ($F_c = F_R - F_g$). So, a person feels heavier at the bottom of the loop. At the top of the vertical circle the size of the reaction force is small or negligible , so a person will feel lighter ($F_c = F_R + F_g$).	• Correct vectors, including relative sizes at the top and bottom of the circle, F_g and F_R only. Fg must be the same for both and Fr must be bigger than F_g at the bottom but smaller than F_g at top. (only accept additional F_c if this shown as the F_{net} not an additional force). OR Recognition that it is the size of the reaction force that the feeling of weight depends on. OR Recognition that reaction force is greatest at the bottom of the circle. OR Equations to show Fc at top and bottom.	• TWO of: - Correct vectors, including relative sizes at the top and bottom of the circle. - At the bottom of the loop, F_R must be greater than F_g to provide the F_c. ($F_c = F_R - F_g$). So, a person feels heavier at the bottom of the loop. - At the top of the vertical circle the size of the reaction force is small or negligible , so a person will feel lighter ($F_c = F_R + F_g$).	• Full answer including accurate diagram, clear justification of larger F_R at bottom compared to top.
(d)	Minimum speed at the top of loop: $F_c = F_g$ $\frac{mv^2}{r} = mg \rightarrow v^2 = rg$ $v^2 = 0.250 \times 9.81 = 2.4525$ Total energy at the top of loop: $mgh + \frac{1}{2}mv^2 = (0.120 + 9.81 + 0.500) + \left(\frac{1}{2} \times 0.120 \times 1.566^2\right)$ $E_T = 0.5886 + 0.14715 = 0.73575$ $mgh + \frac{1}{2}mv^2 = (0.120 \times 9.81 \times 0.500) + \left(\frac{1}{2} \times 0.120 \times 2.4525\right)$ $= 0.5886 + 0.14715 = 0.73575\text{ J}$ Speed of car at the bottom of the loop: $E_k = \frac{1}{2}mv^2 \rightarrow v = \sqrt{\frac{2 \times 0.73575}{0.120}}$ $= 3.50\text{ m s}^{-1}$	• EITHER Stated the equation for total E at top $mgh + \frac{1}{2}mv^2$ OR $F_c = F_g$ OR Correct answer for $v_2 = 2.4525$ OR $v = 1.566\text{ m s}^{-1}$	• EITHER Calculates v and uses this to determine the kinetic energy at the top of the loop: E_k top= 0.14715 J OR Calculates total energy ($E_k + E_p$) at top of loop with one minor error.	• Correct answer for speed at the bottom of the loop.

NØ	N1	N2	A3	A4	M5	M6	E7	E8
No relevant evidence.	1a	2a 1m	3a 1a + 1m 1e	4a 1a +1e	2a + 1m 2a + 1e	2m 1m + 1e	1a + 1m + 1e 2m + 1e 2e	1m + 2e 2a + 2e

Q	Evidence	Achievement	Merit	Excellence
TWO (a)	Gravitational potential energy to both linear kinetic energy (translational)and rotational kinetic energy. / GPE → $E_{k(lin)} + E_{k(rot)}$	• Correct answer in either form.		
(b)	GPE at start → $E_{k(lin)} + E_{k(rot)}$ GPE at start = mgh = 5.50 × 9.81 × 1.34 =72.3 J $E_{k(lin)}$ gained = ½ × 5.50 × 3.40² = 31.8 J $E_{k(rot)}$ gained = 72.3 – 31.8 = 40.5 J as $v = r\omega$ and $E_{k(rot)} = \frac{1}{2}I\omega^2$ $\omega = \frac{3.40}{0.280} = 12.1 \text{ rad s}^{-1}$ $I = \frac{2 \times 40.5}{12.1^2} = 0.553 \text{ kg m}^2$	• GPE at start = 72.3 J OR $E_{k(lin)}$ = 31.8 J *OR* uses $v = r\omega$ to work out ω 12.1 rads^{-1}	• EITHER all 3 of: - GPE lost = 72.3 J - $E_{k(lin)}$ = 31.8 J - $E_{k(rot)}$ = 40.5 J OR Calculates I using GPE → $E_{k(rot)}$ only therefore $E_{k(rot)}$ = 72.3 = $\frac{1}{2}I\omega^2$ $I = \frac{72.3 \times 2}{12.1^2}$ I = 0.987 kg m²	• ALL of: - GPE lost = 72.3 J - $E_{k(lin)}$= 31.8 J - $E_{k(rot}$ = 40.5 J - I = 0.553 kg m2 Accept 0.549 kg m² if using unrounded values.
(c)	In the absence of net external torque, **angular momentum** is conserved. Holding his arms out increases rotational inertia, since mass is further away from the axis of rotation. Since $L = I\omega$, when rotational inertia increases, angular velocity decreases, causing him to spin slower when his arms are outstretched.	• **Angular momentum** is conserved. OR Rotational inertia increases when arms are extended. OR If I increases, then ω decreases.	• Linking $I \propto mr^2$ to mass distribution or increased r. (mathematical relationship not required) Since $L = I\omega$, when rotational inertia increases, angular velocity decreases and **angular momentum** is conserved assuming.	
(d)	$\omega_f = \omega_i + \alpha t$ $7.00 = 3.00 + 4.50\alpha$ $\alpha = 0.889 \text{ rad s}^{-2}$ $\omega_f^2 = \omega_i^2 + 2\alpha\theta$ $49 = 9 + 2 \times 0.889\theta$ $\theta = 22.5 \text{ rad}$ Number of revolutions $= \frac{22.5}{2\pi} = 3.58$ revs	• Correct answer for angular acceleration. OR Correct working for angular displacement with minor error from angular acceleration (i.e. wrong change in ω).	• One error in calculation. E.g. two out of three stages correct OR Correct answer for angular acceleration AND angular displacement: 0.889 rad s^{-2} AND 22.5 rad.	• Correct answer for number of revolutions.

NØ	N1	N2	A3	A4	M5	M6	E7	E8
No evidence	1a	2a or 1m	3a or 1e	4a	2m	3m 2e	1a + 1m + 1e	1m + 2e

Q	Evidence	Achievement	Merit	Excellence
THREE (a)	• Gradient represents ω^2 *where* $\omega = 2\pi f$. • Gradiant is proportional to f^2 because $\omega = 2\pi f$. • So gradient of graph is $4\pi^2 f^2$. • Because graph is linear / gradient is constant then the frequency must be constant .	• Any one bullet point.		
(b)	Calculate gradient, determine ω and therefore use $\omega = 2\pi f = \frac{2\pi}{T}$. Gradient = $\frac{20}{0.02}$ = 1000 this is ω^2. $\omega = 31.2\ rads^{-1}$ $= 2\pi f = \frac{2\pi}{T}$ $T = 0.1986$ Then substitute in to $T = 2\pi\sqrt{\frac{m}{k}}$ $m = 0.0246$ kg	• EITHER **show** working for *T*. Correct calculation of gradient. OR Ccalculation of *m*.	• Correct **show** for *T* and correct answer for *m*.	

(c)	 $T = 0.199$ s, $A = 0.10$ m, $y = 0.04$ m $\theta = \sin^{-1}\frac{0.04}{0.10} = 23.6°$ total angle $= 90 + 23.6 = 113.6°$ It takes 0.199 s to do 360°, so for 113.6°, it takes $\frac{113.6}{360} \times 0.199 = 0.0628$ s Accept other solutions / methods that are reasonable.	• Correct diagram on reference circle. OR Correct angle of 23.6°. OR Correct ω.	• One error in calculation. If use alternative method, with minor error. OR Calculator in degrees.	• Correct answer.

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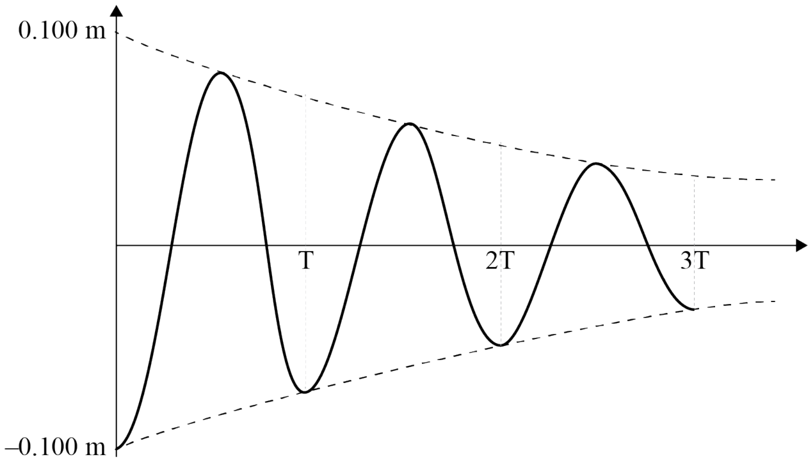
<td>(d)</td>
<td>This is called damping.
The period stays the same, but the amplitude decreases as energy is lost to the surroundings in the form of heat due to friction.

Max amplitude = 0.100 m marked on y-axis. (Cosine curve starting at either +A or –A)
(Decay envelope shape.)
Three cycles
T = 0.199 s</td>
<td>• ONE correct aspect:
This is called damping
OR
Energy lost to surroundings due to friction (resulting in a loss of amplitude.)
OR
Correct cosine shape showing decreased amplitude over 3 cycles.
OR
3 cycles with constant time periods.</td>
<td>• THREE of:
- Damping.
- Energy lost to surroundings in the form of energy due to friction, (resulting in a loss of amplitude.)
- Correct cosine shape showing decreased amplitude over 3 cycles.
- 3 cycles with constant time periods.
- Correct labels and values on axes for amplitude and period.</td>
<td>• ALL of:
- Damping.
- Energy lost to surroundings in the form of due to friction, (resulting in a loss of amplitude.)
- Correct cosine shape showing decreased amplitude over 3 cycles.
- 3 cycles with constant time periods.
- Correct labels and values on axes for amplitude and period.</td>
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</table>

NØ	N1	N2	A3	A4	M5	M6	E7	E8
No relevant evidence.	1a	2a 1m	3a 1a + 1m 1e	4a 2a + 1m 1a + 1e	2m 1m + 1e	3m 2e	1a + 1m + 1e 2m + 1e 1a + 2e	1m + 2e 2a + 2e

Cut Scores

Not Achieved	Achievement	Achievement with Merit	Achievement with Excellence
0 – 6	7 – 12	13 – 18	19 – 24