Question	Type 1 (explanatory) or Type 2 (problem)	B Evidence	A Evidence
4(i)	1		The force exerted by the wire on the ball must include a vertical component (equal and opposite to the weight of the ball).
4(ii)	1		If the speed is to increase then the wire must provide a tangential force component. To produce this the hammer thrower must move their hands (ie the end of the wire) from the centre of the circle (ie it is no longer acting along a radius).

<table>
<tr><th>Question</th><th>Evidence</th><th>1-4 marks</th><th>5-6 marks</th><th>7-8 marks</th></tr>
<tr><td>2(a)</td><td>In order to go round the loop, the centripetal force at the top has to be provided by the weight + reaction force. (In the minimum case the reaction could be zero).
Mathematically $\frac{mv^2}{r} \geq mg$</td><td rowspan="5">Partially correct mathematical solution to the given problems

AND/OR

Incomplete discussion of the underlying physics of this application

OR

Correct mathematical solution to the given problems

OR

Thorough discussion of the underlying physics of this application.</td><td rowspan="5">(Partially) Correct mathematical solution to the given problems

AND

Reasonably thorough discussion of the underlying physics of this application.</td><td rowspan="5">Thorough discussion of the underlying physics of this application

AND

Correct mathematical solution to the given problems.</td></tr>
<tr><td>(b)</td><td>Initial energy = mgh
At the top of the loop energy = kinetic energy+potential energy
$= \frac{1}{2}mv^2 + mgD$
At top minimum speed
$\frac{mv^2}{r} = mg \quad (r = \frac{D}{2})$
$\Rightarrow v^2 = \frac{Dg}{2}$
So combining
$mgh = \frac{1}{2}m\frac{Dg}{2} + mgD$
$h = \frac{1}{4}D + D$
$h = \frac{5}{4}D$</td></tr>
<tr><td>(c)(i)</td><td>Pushing the slider means it has more kinetic energy and so requires less potential energy to reach the energy total needed to complete the loop. Therefore less height is needed.</td></tr>
<tr><td>(ii)</td><td>The height is independent of mass (assuming no friction) so no difference.</td></tr>
<tr><td>(iii)</td><td>In the ellipse the radius of curvature at the top is smaller (less than D / 2).
If the radius is less then less speed is required at the top ($v^2 = rg$).
D is the same so potential energy at top is the same but less kinetic energy is required at the top so the total energy is less so the minimum height is lower.</td></tr>
</table>

<table>
<tr><th>Q</th><th>Evidence</th><th>1-4 marks</th><th>5-6 marks</th><th>7-8 marks</th></tr>
<tr><td>THREE
(a)</td><td>The sensation of weight comes from a reaction force. Satellites are in constant free-fall around the object they are orbiting. In this situation the reaction force is zero, so the satellite appears weightless.</td><td rowspan="5">Thorough understanding of these applications of physics.

OR

Partially correct mathematical solution to the given problems.

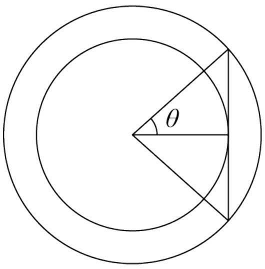
AND / OR

Partial understanding of these applications of physics.</td><td rowspan="5">(Partially) correct mathematical solution to the given problems.

AND / OR

Reasonably thorough understanding of these applications of physics.</td><td rowspan="5">Correct mathematical solution to the given problems.

AND

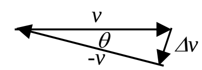
Thorough understanding of these applications of physics.</td></tr>
<tr><td>(b)</td><td>$\frac{mv^2}{r} = \frac{GMm}{r^2}$
In this case $r = R + h$, where R = radius of the Earth and h is altitude of satellite.
Rearranging gives
$\frac{4\pi^2(R+h)^2}{T^2} = \frac{GM}{R+h}$
Rearranging gives
$h = \sqrt[3]{\frac{GMT^2}{4\pi^2}} - R$
Substituting gives h = 1690 km</td></tr>
<tr><td>(c)</td><td>Angular velocity of the Earth = $\frac{2\pi}{24 \times 60 \times 60}$
Angular velocity of the satellite = $\frac{2\pi}{2 \times 60 \times 60}$
Angular velocity of the satellite relative to the Earth
$= \frac{2\pi}{2 \times 60 \times 60}\left[1 - \frac{1}{12}\right]$
$= 8 \times 10^{-4}$ rad s^{-1}</td></tr>
<tr><td>(d)</td><td>

R = radius of Earth
h = altitude of the satellite

$\cos\theta = \frac{R}{R+h}$
$2\theta = 75.6°$</td></tr>
<tr><td>(e)</td><td>As the satellite's orbital radius gets larger, the Earth's gravitational field strength decreases until it becomes smaller than other celestial bodies, and so the satellite will no longer orbit the Earth. So this limits the maximum period. The minimum period is determined by when the satellite enters the Earth's atmosphere.</td></tr>
</table>

Q	Evidence	1-4 marks	5-6 marks	7-8 marks
4 (a)	At the top $\frac{mv^2}{r} = mg$ $r = r_2 - \frac{\pi r_1}{2}$ $v^2 = g(r_2 - \frac{\pi r_1}{2})$	Thorough understanding of these applications of physics. OR Partially correct mathematical solution to the given problems. AND / OR Partial understanding of these applications of physics.	(Partially) correct mathematical solution to the given problems. AND / OR Reasonably thorough understanding of these applications of physics.	Correct mathematical solution to the given problems. AND Thorough understanding of these applications of physics.
(b)	KE at start = KE at top + GPE gained $\frac{mv_i^2}{2} = mg\frac{(r_2 - \frac{\pi r_1}{2})}{2} + mg(2r_2 + r_1 - \frac{\pi r_1}{2})$ $v_i^2 = g(5r_2 - (\frac{3\pi}{2} - 2)r_1$			
(c)	The bat hitting the ball: $M_B V_B = M_B V_{B2} + mV_{Ball}$ (conservation of momentum – appropriate as long as assume batter doesn't apply an impulse during the collision) $\frac{1}{2} M_B V_B^2 = \frac{1}{2} M_B V_{B2}^2 + \frac{1}{2} m V_{Ball}^2$ (conservation of KE as stated in the question) $V_{Ball}^2 = \frac{M_B}{m}\left(V_B^2 - V_{B2}^2\right) = \frac{M_B}{m}\left(V_B + V_{B2}\right)\left(V_B - V_{B2}\right)$ $\left(V_B - V_{B2}\right) = \frac{mV_{Ball}}{M_B}$ $V_{Ball}^2 = \frac{M_B}{m}\left(V_B + V_{B2}\right) \times \frac{mV_{Ball}}{M_B}$ $V_{Ball} = (V_B + V_{B2}) = 2V_B$ (since the bat hardly slows at all)			
(d)	The linear velocity is reduced (there is GPE removed from the initial KE) but the angular velocity is increased (since the radius of the swing is reducing towards zero while the linear velocity is reducing to some fixed positive value).			

Question	Evidence	1-4 marks	5-6 marks	7-8 marks
FIVE (a)	At large angles (> 10º) there is no longer a linear relationship between the displacement and the restoring force.	Thorough understanding of these applications of physics. OR Partially correct mathematical solution to the given problems. AND / OR Partial understanding of these applications of physics.	(Partially) correct mathematical solution to the given problems. AND / OR Reasonably thorough understanding of these applications of physics.	Correct mathematical solution to the given problems. AND Thorough understanding of these applications of physics.
(b)	$F_{NET} = F_{TENSION} - F_{GRAVITY}$ At the bottom, Tension = $Mg + \frac{Mv^2}{r}$ Height energy lost = Mgr = KE gained = $\frac{Mv^2}{2}$ Therefore $2gr = v^2$ Tension = $Mg + \frac{2Mgr}{r} = 3Mg$			
(c)	$T = mg\sin\theta + \frac{mv^2}{r}$ Height lost is $r \sin \theta$ Energy lost $= mgr\sin\theta = \frac{1}{2}mv^2$ So centripetal force $\left(\frac{mv^2}{r}\right) = 2mg\sin\theta$ Gives $T = 2mg = 2mg \sin \theta$ {the centripetal component} + $mg \sin \theta$ {the weight component} Cancel and get $\sin \theta = 2/3$ $\theta = 41.8°$			
(d)	The positive bob will induce a negative charge on the metal plate. This will increase the downward force acting on the bob. The net effect of this is that the restoring force is increased. This leads to a reduction in the period.			

Question mark	Acceptable Answers		Additional Guidance	Mark
17a	• vector velocities at two positions as part of a triangle and third side identified as Δv • Acceleration $a = \Delta v/t$ (i) • Use of trigonometry: $\Delta v/v \approx \sin\theta \approx \theta$ for small angles (ii) • Use of $v = r\theta/t$ (iii) • Combine i, ii, iii to final equation **OR** • Diagram shows components of v with angle turned through • Acceleration $= 2v\sin\theta/t$ • Use of trigonometry: $\Delta v/v \approx \sin\theta \approx \theta$ for small angles • $t = r2\theta/v$ and 2s cancel • Simplify to final equation	**(1)** **(1)** **(1)** **(1)** **(1)** **(1)** **(1)** **(1)** **(1)** **(1)**	Example of diagram  Ignore arrow directions Combine (i) and (ii) $a = v\theta/t$ Substitute for θ using (iii) a = $\frac{v}{t} \times \frac{vt}{r}$ then "t"s cancel Allow other fully correct methods	5
17b(i)	• Correct conversion to angle in radians • $\omega = 5.2$ (rads^{-1})	**(1)** **(1)**	Example of calculation $\omega = 50 \times 2\pi / 60$ s $= 5.24$ rads^{-1}	**2**
17b(ii)	• Reference to $F = mr\omega^2$ • appreciation that r is large **Or** (the equipment) has a **high** (linear) velocity	**(1)** **(1)**	Alt: mass (of equipment) could be large	**2**
17b(iii)	• use of $r\omega^2$ • $a = 25g$ **and** appropriate comment	**(1)** **(1)**	Show that value gives 22.5g Allow reverse argument starting with 25g to ω=5.28 rads^{-1} Example of calculation $a = 8.8$ (m) x 5.24^2 (rads^{-1})^2 $a = 238$ (ms^{-2}) ÷9.81 (ms^{-2}) $= 24.6 \times g$	**2**

(Total for Question 17 = 11 marks)