Name: _____

Circular Motion

Mark Scheme

Date:

Time:

Total marks available:

Total marks achieved: _____

Mark Scheme

Q1.

Question Number	Answer	Mark
	B	1

Q2.

Question Number	Answer	Mark
	C	1

Q3.

Question Number	Answer	Mark
	D	1

Q4.

Question Number	Answer	Mark
	B	1

Q5.

Question Number	Answer	Mark
	B	1

Q6.

Question Number	Acceptable answers	Additional guidance	Mark
	B The two forces acting on the mass are its weight (vertically down) and a tension in the thread.		1
	A assumes there is a centripetal force only C assumes there is an additional centripetal force D assumes the additional centripetal force acts away from the centre of the circle		

Q7.

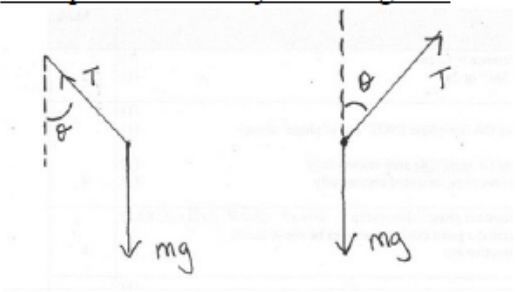
Question Number	Answer	Mark
	A	1

Q8.

Question Number	Acceptable answers	Additional guidance	Mark
(a)	• use of $F = Gm_1m_2/r^2$ (1) • force = 6.5×10^{31} N (1)	Example of calculation $F = 6.67 \times 10^{-11}$ N m^2 kg^{-2} × 29 × 1.99×10^{30} kg × 36 × 1.99×10^{30} kg / $(6.5 \times 10^{10}$ m$)^2$ force = 6.5×10^{31} N	2

Question Number	Acceptable answers	Additional guidance	Mark
(b)	**Either** • use of $F = mv^2/r$ ecf from (a) (1) • use of $v = 2\pi r/T$ (1) • $T = 1.1 \times 10^6$ s (1) **Or** • use of $F = m\omega^2 r$ ecf from (a) (1) • use of $\omega = 2\pi/T$ (1) • $T = 1.1 \times 10^6$ s (1)	Example of calculation $F = mv^2/r = m(2\pi r/T)^2/r$ $T^2 = 4\pi^2 mr/F$ $= 4\pi^2 \times 29 \times 1.99 \times 10^{30}$ kg × 3.6×10^{10} m / 6.5×10^{31} N $= 1.21 \times 10^{12}$ s^2 $T = 1.12 \times 10^6$ s = 18700 min = 312 hours = 13 days	3

Q9.

Question Number	Answer		Mark
	Free body force diagram showing 2 forces only Weight/W/mg Tension / T (Each additional forces e.g. horizontal component or resultant force, 1 mark penalty) **If θ is angle to the vertical then**: (Resolving vertically): $T\cos\theta = mg$ (Resolving horizontally): $T\sin\theta = mv^2/r$ **Or** $T\sin\theta = mr\omega^2$ Derives $\tan\theta = v^2/rg$ **and** links to observations **Or** Derives $\tan\theta = r\omega^2/g$ **and** links to observations If angle to horizontal is used candidates can score MP3 and 4.[then sin and cos swop over and tan of angle will be reciprocal of above] <u>Examples of free body force diagrams</u>  (full credit for the last 3 marks can be given to candidates who draw a vector triangle and derive $\tan\theta = T_{horzt}/mg$ and then $\tan\theta = r\omega^2/g$ **and** observation)	**(1)** **(1)** **(1)** **(1)** **(1)**	**5**
	Total for question		**5**

Q10.

Question Number	Answer		Mark
(a)	Evidence of frictional force = $(0.35 \times mg)$ Use of $F = mr\omega^2$ **Or** $F = mv^2/r$ Use of $\omega = 2\pi/T$ **Or** $v = 2\pi r/T$ $t = 3.0$ s Example of calculation frictional force = 0.35×20 kg $\times 9.81$ m s^{-2} = 68.7 N $F = mr\omega^2$ $\omega = \sqrt{}$ (68.7 N / (20 kg $\times$ 0.80 m) ω =2.1 rad s^{-1} $t = 2\pi/2.1$ rad s^{-1} $t = 3.0$ s	(1) (1) (1) (1)	4
(b)	There would be no difference Both expressions for force depend on mass **Or** algebraic equation for ω or T derived (could be in the working for (a)) showing ω or T independent of m **Or** statement that masses cancel if supported by evidence in (a)	(1) (1)	2
	Total for question		6

Q11.

Question Number	Answer		Mark
(a)	Only (moving) charged particles are deflected by a magnetic field **Or** Only charged particles can be accelerated to produce a beam	(1) (1)	1
(b)	Into the page	(1)	1
(c)	Use of $F = mv^2/r$ **Or** use of $r = p/BQ$ Use of $F = Bqv$ **Or** use of $p = mv$ $m = 6.64 \times 10^{-26}$ kg Example of calculation $mv^2/r = Bqv$ $m = Bqr/v$ =(0.673 T $\times 1.6 \times 10^{-19}$ C $\times 7.40 \times 10^{-2}$ m) / 1.20×10^5 m s^{-1} $m = 6.64 \times 10^{-26}$ kg	(1) (1) (1)	3
(d)	Semicircle drawn starting from same initial point and a smaller radius	(1)	1
	Total for question		6

Q12.

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	• The ions experience a force perpendicular to their velocity (and the magnetic field) (1) • The (resultant) force on the ions causes an acceleration at right angles to their velocity (1) **Or** There is a magnetic force acting towards the centre of the path	For velocity accept direction of motion or direction of travel	2

Question Number	Acceptable Answer	Additional Guidance	Mark
(ii)	• Use of $r = \frac{mv}{BQ}$ (1) • $r = 0.23$ m (1)	Example of calculation: $r = \frac{mv}{BQ}$ $= \frac{(34.97 \times 1.66 \times 10^{-27})\text{kg} \times 2.2 \times 10^{5}\,\text{m s}^{-1}}{0.35\,\text{T} \times 1.6 \times 10^{-19}\,\text{C}} = 0.228\,\text{m}$	2

Question Number	Acceptable Answer	Additional Guidance	Mark
(iii) 1	• path drawn with less curvature (less overall deflection) (1)	MP1 awarded for path in the magnetic field	1

Question Number	Acceptable Answer	Additional Guidance	Mark
(iii) 2	• ions are more massive (1) • ions have the same charge so the radius of the path would be greater (1)		2

Q13.

Question Number	Answer		Mark
(a)(i)	$R = 9.32$ kN Example of answer $R = 950\ \text{kg} \times 9.81\ \text{m s}^{-2}$ $R = 9320$ N	(1)	1
(a)(ii)	Use of $F = mv^2/r$ $R = mg - mv^2/r$ $R = 2480$ N ecf their value of R Example of calculation $R = 9320\ \text{N} - (950\ \text{kg} \times 12.0^2\ \text{m}^2\ \text{s}^{-2} / 20.0\ \text{m})$ $R = 2480$ N	(1) (1) (1)	3
(b)	An answer that either states implicitly or implies that 'The required centripetal force > mg and so cannot be provided'.	(1)	1
	Total for question		5

Q14.

Question Number	Answer		Mark
(a)	Use of $v = 2\pi r/t$ **Or** $v = r\omega$ **and** $T = 2\pi/\omega$ $t = 1.5 \times 10^3$ s [24.6 minutes] Example of calculation $t = 2\pi r/v$ $t = (2\pi \times 61\text{ m}) / 0.26\text{ m s}^{-1}$ $t = 1473$ s	**(1)** **(1)**	**2**
(b)	Use of $F = mv^2/r$ $F = 11$ N Example of calculation $F = 9.7 \times 10^3\text{ kg} \times (0.26\text{ m s}^{-1})^2 / 61\text{ m}$ $F = 10.7$ N	**(1)** **(1)**	**2**
(c)(i)	Three arrows all pointing to the centre of the circle (accept free hand and lines of varying length)	**(1)**	**1**
* **(c)(ii)**	(QWC – Work must be clear and organised in a logical manner using technical wording where appropriate) Maximum at C / bottom **and** Minimum at A / top At C contact/reaction force (R) greater than weight (accept $R - W = mv^2/r$ or $R = W + mv^2/r$) At A contact/reaction force is less than the weight. (accept $W - R = mv^2/r$ or $R = W - mv^2/r$) Any statement that centripetal force / acceleration is provided by weight/reaction **Or** centripetal force is the resultant force This is a qwc question so a bald statement of the equations can score the marks but to get full marks there must be clear explanation in words.	**(1)** **(1)** **(1)** **(1)**	**4**

Q15.

Question Number	Answer		Mark
(a)	Velocity/direction changing **Or** (object is) accelerating Force towards centre of circle	**(1)** **(1)**	**2**
(b)	High(er) speed means large(r) force **Or** small(er) radius means large(r) force (For sharp bends) centripetal/resultant/required <u>force</u> would need to be greater than maximum frictional force **Or** (for sharp bends) friction cannot provide the (required) centripetal/resultant force	**(1)** **(1)**	**2**
(c)(i)	Resolving forces vertically $\underline{N} \sin \theta = mg$ Resolving forces horizontally $\underline{N} \cos \theta = mv^2/r$ Division of vertical equation by horizontal equation to get correct answer	**(1)** **(1)** **(1)**	**3**
(c)(ii)	Use of $\tan \theta = gr/v^2$ $\theta = 57°$ <u>Example of calculation</u> $\tan \theta = (9.81 \text{ m s}^{-2} \times 18.7 \text{ m})/ (11.0 \text{ m s}^{-1})^2$ $\theta = 56.6°$	**(1)** **(1)**	**2**
	Total for question		**10**

Q16.

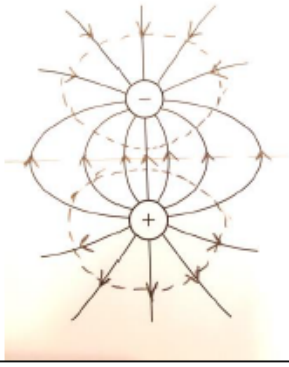
Question Number	Answer		Mark
(a)(i)	See $F = GMm/r^2$	(1)	
	Equated to mg to give required expression **Or** use of g = F/m	(1)	2
(a)(ii)	Use of $g = \omega^2 r$ OR $g = v^2/r$	(1)	
	Use of $\omega = 2\pi/T$ OR $v = 2\pi r/T$	(1)	
	Correct algebra leading to expression given	(1)	3
	Example of calculation: $\omega^2 r = \frac{GM}{r^2}$ $\left(\frac{2\pi}{T}\right)^2 = \frac{GM}{r^3}$ $r^3 = \frac{GMT^2}{4\pi^2}$		
(a)(iii)	See T = 24 hours	(1)	
	T converted into s	(1)	
	$r = 4.2 \times 10^7$ m	(1)	3
	Example of calculation: $T = 24 \times 60 \times 60$ s = 86 400 s $r^3 = \frac{GMT^2}{4\pi^2} = \frac{6.67\times10^{-11}\ \text{N m}^2\ \text{kg}^{-2} \times 6.0\times10^{24}\ \text{kg} \times (86400\ \text{s})^2}{4\pi^2} = 7.57\times10^{22}\ \text{m}^3$ $r = \sqrt[3]{7.57\times10^{22}\ \text{m}^3} = 4.23\times10^7\ \text{m}$		
(b)	The satellite must rotate with the Earth **Or** the satellite must be in a geosynchronous orbit **Or** any non-equatorial orbit would cause the satellite to move N-S		1
	Total for question		9

Q17.

Question Number	Answer		Mark
(i)	Outward spiral from centre in either direction, minimum of two complete loops	(1)	1
(ii)	Direction consistent with diagram: Clockwise path, field out of page Anticlockwise path, field into page	(1)	1
(iii)	Electric field/p.d. between dees causes (resultant) force/acceleration	(1)	
	Proton makes half a revolution in half a cycle of the a.c. **Or** facing dee (always) negative when proton reaches gap. **Or** whenever the proton gets to a gap, the p.d. has reversed	(1)	
	k.e./speed (only)increases each time the proton crosses the gap **Or** work done by the field in the gap increases the k.e.	(1)	3
(iv)	$Bev=mv^2/r$ **Or** $r=p/Be$	(1)	
	$v=2\pi r/T$	(1)	
	$T=1/f$ (seeing $f=v/(2\pi r)$ scores MP2 & 3)	(1)	
	Or		
	$Bev=mr\omega^2$	(1)	
	$v=r\omega$	(1)	
	$\omega=2\pi f$ (seeing $v/r=2\pi f$ scores MP2 & 3)	(1)	3
(v)	Use of $B=2\pi fm/e$ with mass of proton	(1)	
	$f=1.8\times10^4$ Hz	(1)	2
	<u>Example of calculation</u> $f=eB/2\pi m$ $f=(1.6\times10^{-19}\text{ C}\times1.2\times10^{-3}\text{ T})/(2\pi\times1.67\times10^{-27}\text{kg})$ $f=1.8\times10^4$ Hz		

Q18.

Question Number	Acceptable answers		Additional guidance	Mark
(a)	• Replace Work W by force × distance	(1)	Alternative method: Consider one revolution of axle , Load rises $2\pi r$	
	• Replace distance ÷ time by velocity v	(1)	Work done = $2\pi rF$	
	• Use $v=r\times$ Angular velocity	(1)	Time taken = $2\pi\div\omega$	
	• Recognise $F\times r$ is the moment of F	(1)	Power = Work ÷ time= $2\pi rF\div2\pi/\omega$ to give reqd eq	4

Question Number	Acceptable answers		Additional guidance	Mark
(b)(i)	• Arrow away from + charge **Or** arrow towards − charge	(1)	MP3 dependent on lines being perpendicular in MP2 	3
	• At least 3 Equipotential lines, perpendicular to field lines	(1)		
	• Symmetrical about vertical/horizontal axis **and** not touching/crossing	(1)		

Question Number	Acceptable answers		Additional guidance	Mark
(b)(ii)	• Use of $F = \frac{Q_1 Q_2}{4\pi\varepsilon_o r^2}$	(1)	Example of calculation: $F = 8.99\times10^{9}\,\text{Nm}^2\text{C}^{-2}\,\frac{(0.1\times10^{-6}\,\text{C})^2}{(0.05\text{m})^2}$	2
	• $F = 0.036$ (N)	(1)	$F = 0.036$N	

Question Number	Acceptable answers		Additional guidance	Mark
(c)	• Use of moment = Fx	(1)	Show that value gives 3.2×10^{-3} Nm and 0.64 W	4
	• Expression for correct moment	(1)	Example of calculation: Moment $= 0.036\text{N}\times0.04\text{m}\times2 = 2.89\times10^{-3}\,\text{Nm}$	
	• Use of power = moment of force x angular velocity	(1)		
	• Only realistic possibility is pond pump and $P = 0.6$W (calculated answer could also be force and then comparison with b(i))	(1)	Power $= 2.89\times10^{-3}\,\text{N m}\times200\text{s}^{-1} = 0.58$W	