Marking Scheme

#1

Question			Marking details	AO1	AO2	AO3	Total	Maths	Prac
	(a)		$\frac{1}{2}mv^2 = eV$ applied (1) $d = vt$ used (1) $s = \frac{1}{2}at^2$ used for vertical motion (1) $a = \frac{Vq}{md}$ (1) Substitutions & ok algebra (1)	 1	1 1 1 1		5	5	
	(b)		Both are -ve charges **OR** move same direction (1) Independent of m and q, hence, yes (1)			2	2		
			Question total	**1**	**4**	**2**	**7**	**5**	**0**

#2

Question			Marking details	AO1	AO2	AO3	Total	Maths	Prac
2	*(a)*	(i)	$\omega = \frac{\text{angle swept out}}{\text{time taken}}$ [or in words] Or angle [accept: number of radians] swept out per unit time [or per second]	1			1		
		(ii)	Clear use of $\omega = \frac{v}{r}$ or equivalent (1) Convincing algebra (1)	1	1		2	1	
	(b)	(i)	Substitution into: $F = m\frac{v^2}{r}$ or equivalent either before or after rearrangement (1) v = 1.35 km s^{-1} (1)	1	1		2	1	
		(ii)	$\frac{GMm}{r^2} = \frac{mv^2}{r}$ or equivalent with M and m correctly identified (1) m cancels so speed of moon of twice the mass would be the same as that of Deimos. [Must be supported by argument even if argument not clear enough to give first mark.] (1) or in words, e.g. Equivalence of gravitational and inertial mass however expressed, [e.g. the force would be double and the mass is doubled] (1) Hence speed the same (1) or Another identical moon next to the existing one will orbit at the same speed (1), so the composite moon [of double the mass] will orbit at that speed (1).		2		2		
			Question 2 total	3	4	0	7	2	0

#3

Question			Marking details	AO1	AO2	AO3	Total	Maths	Prac
	(a)		2.1 eV required to free electron **OR** subbing into Einstein's (1) Remainder (8.2 eV) can become KE (1) 8.2 V corresponds to 8.2 eV (for electrons) (1) +ve will stop electrons from escaping (or attractive force) (1) Hence, +8.2 V is just enough to stop any electrons escaping (or any greater and the electrons can't escape etc.) (1)	1 1	 1 1 1		5		
	(b)		$E = \frac{Q}{4\pi\varepsilon_0 r^2}$ quoted **OR** used **OR** implied (1) Hence, $E = \frac{V}{r}$ **OR** Q obtained using V equation (59.3 pC) (1) Answer = 126 [V m^{-1}] **OR** 1.26 if [V cm^{-1}] (1)	1	 1 1		3	2	
			Question total	**3**	**5**	**0**	**8**	**2**	**0**

#4

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
	(a)		Horizontal line[s] with direction indicated from X to Y	1			1		
	(b)	(i)	Substitution into $F = \frac{Ve}{d}$ shown: $\frac{1800 \times 1.6 \times 10^{-19}}{3.2 \times 10^{-3}}$ (1) $F = 9.0 \times 10^{-14}$ [N] (1)	1	1		2	2	
		(ii)	[Gain in E_k = Work done by field] Gain in $E_k = 9.0 \times 10^{-14} \times 3.2 \times 10^{-3}$ (1) (**ecf** on F) Gain in $E_k = 2.88 \times 10^{-16}$ J **unit mark** (1) **Alternative:** $W = 1.6 \times 10^{-19} \times 1800$ (1) $W = 2.88 \times 10^{-16}$ J **unit mark** (1) [Accept 1 800 eV **unit mark**]	1	1		2	2	
		(iii)	$x = ut + ½ at^2$ and $u = 0$ (all possible by implication) (1) $a = \frac{F}{m}$ **and** substitution step: **ecf** on F e.g. $t^2 = \frac{2 \times 3.2 \times 10^{-3} \times 9.11 \times 10^{-31}}{9.0 \times 10^{-14}}$ (1) $t = 2.54 \times 10^{-10}$ [s] (1) **Alternative:** $½ mv^2 = 2.88 \times 10^{-16}$ to calculate v (1) Application of $x = \frac{(u+v)t}{2}$ (1) **ecf** on v $t = 2.54 \times 10^{-10}$ [s] (1)	1	1 1		3	3	
	(c)		F doubled (explained from $\frac{Ve}{\frac{1}{2}d}$) (1) $W = 2F \times \frac{d}{2}$ so no change (1) **Accept:** $W = QV$ and Q stated to be constant (1) so W remains unchanged (1)			2	2		
			Question total	**4**	**4**	**2**	**10**	**7**	**0**

#5

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
6	*(a)*		$V \propto \frac{1}{r}$ or equivalent or $\frac{-0.72 \times 10^6}{3}$ seen (accept 0.73) [1] V shown as – 0.24 × 10⁶ [J kg⁻¹] [1] Accept answers based on determination of			2	2	1	
	(b)	(i)	Substitution: $E_P = 600 \times [–] 0.72 \times 10^6$ [1] $E_P = [–] 4.3 \times 10^8$ [J] [1]	1	1		2	1	
		(ii)	Concept: $E_k = -E_P$ or equivalent [1] Substitution: 4.3×10^8 ecf $= ½ \times 600 \times v^2$ or $v = \sqrt{2 \times 0.72 \times 10^6}$ [1] $v = 1.2$ k[m s⁻¹] [1]		3		3	2	
	(c)		Equation used to show that g at $2r$ should be ¼ of surface value or determined i.e. g at $2r = 0.15(5)$ N kg⁻¹ or $gr^2 = k$ or equation used to calculate mass of Pluto [1] Good tangent [1] Gradient calculated e.g. $\frac{0.56 \times 10^6}{3 \times 1.18 \times 10^6} = 0.15[8]$ (approx.) [1] Appropriate comment or analysis to show that $g \propto \frac{1}{r^2}$ [1]			4	4	3	
			Question 6 total	**1**	**4**	**6**	**11**	**7**	**0**

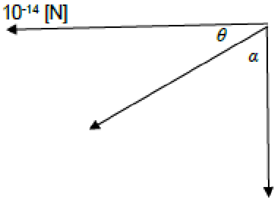
#6

Question			Marking details	AO1	AO2	AO3	Total	Maths	Prac
				Marks available					
	(a)	(i)	<table><tr><th></th><th>Advantage</th><th>Disadvantage</th></tr><tr><td>Ben (ruler)</td><td>Easy to use/convenient / quicker</td><td>Inaccurate [only to ± 1 mm] / reference to parallax errors / difficulty in supporting ruler / may touch spheres</td></tr><tr><td>Sarah (rod)</td><td>Diameter measured accurately / greater accuracy</td><td>Diameter/radius of spheres need to be known beforehand / difficult to judge one complete rotation / difficult to measure angle [of rotation] / difficult to set-up / thread overlapping</td></tr></table>4 × 1 mark - one response required from each cell.		4		4		4
		(ii)	**Any ×(1) from:** • Pins/markers on ruler • Marker on cylinder • Measure diameter of spheres • Mark point at centre of each sphere and use a travelling microscope to measure the separation • Fix the ruler close to spheres • Smaller diameter rod • Use of Vernier calipers (for Ben) Don't accept repeat readings			1	1		1
	(b)	(i)	$F = 9.81 \times 10^{-5}$ N (1) Use of $F = \frac{9 \times 10^9 Q_1 Q_2}{r^2}$ (1) $Q_1 Q_2 = 4.36 \times 10^{-18}$ [C^2] (1)	1	1 1		3	3	3
		(ii)	$Q = (4.36 \times 10^{-18})^{1/2}$ determined (or use of 4.4×10^{-18}) = 2.09×10^{-9} C (1) Area under graph calculated: $3.2 \times 10^{-6} \times 0.65 \times 10^{-3}$ = 2.08×10^{-9} C (1) **Alternative:** Area, $Q = 2.08 \times 10^{-9}$ (1) So $QQ = (2.08 \times 10^{-9})^2 = 4.3 \times 10^{-18}$ C^2 (1)			2	2	2	2
		(iii)	$n = \frac{2.09 \times 10^{-9}}{1.6 \times 10^{-19}} = 1.31 \times 10^{10}$ electrons **ecf** on Q		1		1	1	1
			Question total	**1**	**7**	**3**	**11**	**6**	**11**

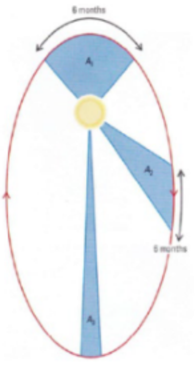
#7

Question				Marking details	Marks available AO1	AO2	AO3	Total	Maths	Prac
	(a)	(i)		Potential at infinity = 0 (1) <u>Work done</u> on object to get to infinity, [therefore initial energy must be negative] (or equivalent) (1)	2			2		
		(ii)	I	Zero (1) No change in potential (or on same 'equipotential'). Do not accept r unchanged unless reference made to potential unchanged (1)	2			2		
			II	ΔV = (-1.79) – (-1.31) (1) Change in gravitational E_p = [-]144 M[J] (1)		2		2	2	
		(iii)		V at Moon surface calculated = -2.82 M[J] per kg (1) Loss in E_p = $m \times 0.63$ MJ (ignore –ve sign) (1) **ecf** on V at Moon surface $\frac{1}{2} mv^2 = m \times 0.63 \times 10^6$ (1) $v = (1.26 \times 10^6)^{1/2}$ [m s^{-1}] = 1.12×10^3 [m s^{-1}] (1) **Alternative:** E_p at Moon = -846 M[J] Total energy at D = -657 M[J] (1) Loss in E_p (gain in E_k) = 189 M[J] (1) $v = 1.12 \times 10^3$ [m s^{-1}] (1)	1	1 1 1		4	4	
	(b)			**Benefits - Any × (1) from:** • Easier for humans to survive on Moon if water present • Help understand origin of Earth/Moon system • To advance science • Generate interest in science/space exploration • Develop new technologies • Create jobs **Costs - Any × (1) from:** • Funding could have been used to address Earth based issues • Little current impact on society • Pollution of Moon			2	2		
				Question total	**5**	**5**	**2**	**12**	**6**	**0**

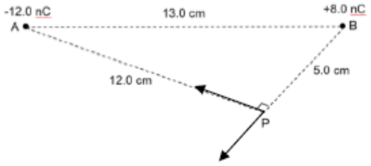
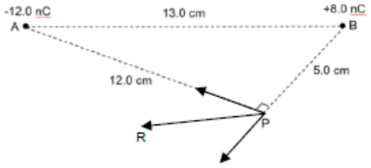
#8

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
8	*(a)*		**Similarity**: Both are vectors or both obey inverse square law or both have infinite range [1] **Difference:** Gravitational fields are attractive only, whereas electric fields can be attractive or repulsive. Or gravitational fields act on masses, electric fields act on charges. Accept, gravitational field is much weaker than electric field [1]	2			2		
	(b)	(i)	Substitution and answer $W = mg$ = 9.4 × 10⁻¹⁴ [N] [1] Substitution $E = \frac{V}{d} = \frac{150}{5.0\times10^{-2}}$ [1] Substitution and answer $F_E = Eq$ = 7.2 × 10⁻¹⁴ [N] [1]	1	1 1		3	2	
		(ii)	F_E = 7.2 × 10^{-14} [N]  W = 9.4 × 10^{-14} [N] F_E and W vectors correctly drawn and labelled (including directions) [1] Resultant direction of movement shown - no precision required and ecf if F_E vector drawn to the right [1] θ = 52.5° or α = 37.5° calculated and shown on diagram (or equivalent, e.g. bearing 217.5° stated) [1] Accept scale drawings	1	1 1		3	3	
	(c)		$F_{res} = \sqrt{(9.4\times10^{-14})^2+(7.2\times10^{-14})^2}$ or F_{res} = 1.18 × 10^{-13} [N] seen or in (b)(ii) [1] $a\left[=\frac{F}{m}\right] = \frac{1.18\times10^{-13}}{9.6\times10^{-15}}$ or a = 12.3 [ms^{-2}] seen [1] Substitution and rearrangement of $x = ½at^2$ i.e. $t^2 = \frac{0.04}{12.3}$ [1] t = 0.06 [s] Accept 0.057 [s] [1]		4		4	3	
			Question 8 total	**4**	**8**	**0**	**12**	**8**	**0**

#9

Question			Marking details	AO1	AO2	AO3	Total	Maths	Prac
				Marks available					
(a)			Areas and time periods shown correctly or described [1] $A_1 = A_2$ (= A_3) indicated [1]  6 months	2			2		
(b)			$\frac{mv^2}{r} = \frac{GMm}{r^2}$ [1] $v = \frac{2\pi r}{T}$ [1] Substitution and clear algebra step shown [1] **Or** $mr\omega^2 = \frac{GMm}{r^2}$ [1] $\omega = \frac{2\pi}{T}$ [1] Substitution and clear algebra step shown [1]	1	1 1		3	2	
(c)	(i)		$\omega = \frac{2\pi}{(7.7 \times 3\,600)}$ or 2.26(7) × 10^{-4} rads^{-1} seen [1] $M = \frac{(2.27 \times 10^{-4})^2 \times (9.4 \times 10^6)^3}{6.67 \times 10^{-11}}$ substitution and re-arrangement [1] M = 6.39[8] × 10^{23} k[g] [1]		3		3	3	
	(ii)	I	Substitution into $V_g = -\frac{GM}{R}$ i.e. $V_g = -\frac{6.67 \times 10^{-11} \times 6.4 \times 10^{23}}{9.4 \times 10^6}$ [1] V_g = - 4.5(4) × 10^6 [J kg^{-1}] [1]	1	1		2	2	
		II	V_g at orbit of Deimos = $-\frac{6.67 \times 10^{-11} \times 6.4 \times 10^{23}}{2.35 \times 10^7}$ = - 1.8(2) × 10^6 J kg^{-1}[1] ΔV = - 1.82 + 4.54 = 2.72 M[J kg^{-1}] [1] Energy available per kg of fuel = 0.6 × 4.4 = 2.64 M[J kg^{-1}] [1] Scientists should not attempt manoeuvre [1] [**ecf** based on calculations]			4	4	3	
	(iii)		One of: • g is not constant [over the distance between orbits] • g decreases as height increases • work done per metre decreases as height increases • field is not uniform		1		1		
			Question total	**4**	**7**	**4**	**15**	**10**	**0**

#10

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
7	(a)		Electric field strength, E, is the force per unit charge [on a small positive test charge placed at the point]. (1) Electric potential, V, [at a point] is the work done per unit charge [in bringing the charge] from infinity [to that point]. (1) E- vector **and** V- scalar (both needed) (1)	3			3		
	(b)	(i)	 Both arrows seen. Ignore length of arrows. [Must be along dotted lines]	1			1		
		(ii)	 R correctly drawn and labelled [ecf]. Ignore length of arrow.		1		1		
		(iii)	E at P due to A (–12.0 nC) = 7 500 N C^{-1} (1) E at P due to B (+8.0 nC) = 28 800 N C^{-1} (1) (Deduct 1 mark for powers of 10 error) Resultant field strength at P = $(7\,500^2 + 28\,800^2)^{1/2}$ = 29 760 N C^{-1} (1) (**ecf** on both values of E) [or using horizontal and vertical components] Correct trigonometric relationship applied e.g. between R and A: $\theta = \cos^{-1}\left(\frac{7500}{29760}\right)$ = 75.4° (or 14.6° between R and B) [accept 2 sf and different ways of expressing directions] (1)		4		4	4	
	(c)	(i)	V_P due to A (–12.0 nC) =[–] 900 V V_P due to B (+ 8.0 nC) = [+] 1440 V **Both potentials regardless of signs** (1) Correct sign convention [and addition clearly shown] (= + 540 V) (1) **Alternative** $\therefore V_P = \frac{1}{4\pi\varepsilon}\left\{\frac{-12\times10^{-9}}{12\times10^{-2}} + \frac{8\times10^{-9}}{5\times10^{-2}}\right\}$ values(1) and signs (1)		2		2	2	
		(ii)	Correct substitution into $W = q\Delta V$ i.e -1.6 $\times$ 10^{-19} (+540 – 0) (1) **Or** W = - 8.64 $\times$ 10^{-17} J seen (accept 540 eV converted into J) Hence gain in E_k = (+) 8.64 $\times$ 10^{-17} J (1) (+) can be awarded by implication	1	1		2	1	
	(d)		de Broglie $\lambda = \frac{h}{p}$ (1) Electron accelerates (or velocity or E_k increases) towards point P, **so** momentum increases (need to explain why momentum increases here) (1) So λ decreases (1) Ecf from (c) on marks 2 and 3: If $\Delta E_k < 0$ then opposite answer required.	1	1 1		3		
			Question 7 total	**6**	**10**	**0**	**16**	**7**	**0**