Marking Scheme

#1

Question		Marking details	Marks available					
			AO1	AO2	AO3	Total	Maths	Prac
2	*(a)*	Zero distance from Sun to line of action of force accept zero perpendicular distance or [line of action of] force is straight through [centre of] Sun		1		1		
	(b)	Work $= 2.15 \times 10^{16} \times 2.0 \times 10^{12} \times \cos 64°$ [1] $= 1.88 \times 10^{28}$ J **unit mark** [1]	1	1		2	2	
	(c)	Work = ΔE_k declared as strategy **or** implied by conclusion ecf from (b) provided comment made [1] Intermediate step: $E_{kA} = 9.94 \times 10^{28}$ [J] **or** $E_{kB} = 1.18 \times 10^{29}$ [J] **or** $v_B^2 - v_A^2 = 2.24 \times 10^6$ [m² s⁻²] or correct substitution into $\frac{1}{2}mv_B^2 - \frac{1}{2}mv_A^2$ [1] $E_{kB} - E_{kA} = 1.86 \times 10^{28}$ [J] **clearly arrived at** [1]			3	3	2	
		Question 2 total	**1**	**2**	**3**	**6**	**4**	**0**

#2

Question		Marking details	Marks available					
			AO1	AO2	AO3	Total	Maths	Prac
	(a)	Distance up ramp = $\frac{1.10\text{ m}}{\sin 15°}$ [= 4.25 m or by implic] [1] Power in = $\frac{960\text{ N} \times 4.25\text{ m}}{35\text{ s}}$ **ecf on 4.25 m** [1] = 117 [W] **no ecf** [1]		3		3	2	
	(b)	Grav PE gained by piano = $320 \times 9.81 \times 1.10$ [J] [= 3.45 kJ] or by implication [1] Efficiency = $\frac{3453}{960 \times 4.25} \times 100\%$ **[ecf on top or bottom]** [1] or Efficiency = $\frac{99\text{ [W]}}{117\text{ [W]}} \times 100\%$ **[ecf on top or bottom]** = 85 [%] or 0.85 **no ecf** [1]		3		3	2	
	(c)	KE of piano $\cong \frac{1}{2} \times 320 \times \left(\frac{4.25}{35}\right)^2 = 2.4$ J [1] Negligible compared with hauling work [or] GPE gained, so *not* a major cause of inefficiency [1] **Alternative answer** KE got back at the end of the process... [1] ... as piano comes to rest if hauling stopped a little before required height rise [1]			2	2	1	
		Question total	**0**	**6**	**2**	**8**	**5**	**0**

#3

Question			Marking details	AO1	AO2	AO3	Total	Maths	Prac
				Marks available					
9	(a)		Conversion 4.32 × 10^6 × 1.6 × 10^{-19} i.e. 6.912 × 10^{-13} [J] (1) Rearrangement for v i.e. $v = \sqrt{\frac{2E}{m}}$ (1) Answer = 1.44 × 10^7 m s^{-1} (1)		3		3	2	
	(b)		24 total energy 'kicks' (or 2 per revolution) (1) 4.32 MeV divided by 24 (=180 000) (1) Also need to divide by 2e, Answer = 90 000 V (1) (2 marks for 180 kV, 1 mark for 360 kV, 2.16 MV →1 mark)		3		3	2	
	(c)		Equating: $m\omega^2 r = Bqv$ (1) or $\omega = \frac{Bq}{m}$ Rearrangement: $f = \frac{Bq}{2\pi m}$ (1) By implication can give 2 marks for this Answer = 3.6 MHz (ecf on part (b) i.e. using 1e instead of 2e 1.8 MHz) (1)		3		3	2	
			Question 9 total	**0**	**9**	**0**	**9**	**6**	**0**

#4

Question			Marking details	AO1	AO2	AO3	Total	Maths	Prac
				Marks available					
2	(a)		Energy cannot be created or destroyed only changed from one form to another	1			1		
	(b)	(i)	Length from top of pendulum = 2 cos 48° = 1.34 [m] (1) Height pendulum rises = 2.00 – 1.34 = 0.66 [m] (1)		2		2	2	
		(ii)	$\frac{1}{2}mv^2 = mgh$ (1) v = 3.60 [m s^{-1}] (1)		2		2	2	
	(c)	(i)	The vector sum of momentum before a collision equals the vector sum of momentum after collision / Accept total for vector sum of (1) provided no external forces act (1)	2			2		
		(ii)	$m_b v_b$ = 1.91 × 3.6 ecf (1) v = 687(.6) or 688 [m s^{-1}] (1)		2		2	2	
	(d)		**Any 2 × (1) from:** - Students over the age of sixteen - Legitimate reason for scientific learning - Needs to be transported through school play ground -Possible dangers in transporting - Risk assessment made			2	2		
			Question 2 total	**3**	**6**	**2**	**11**	**6**	**0**

#5

Question			Marking details	AO1	AO2	AO3	Total	Maths	Prac
				Marks available					
5	*(a)*		E = [2×] 9.11 × 10^{-31} × c^2 or $m = \frac{9.11 \times 10^{-31}}{1.66 \times 10^{-27}}$ [= 0.000549 u] [1] Conversion to eV i.e. dividing by 1.6 × 10^{-19} or × 931 [1] 1.025 MeV seen or 2 × 9.11 × 10^{-31} × $\frac{(3 \times 10^8)^2}{1.6 \times 10^{-19}}$ or 2 × 0.000549 × 931 [1]		3		3	3	
	(b)		Excess energy or 0.01 MeV [1] Equal amounts shared by electrons & positron due to equal (light) masses [1]		2		2		
	(c)		0.5 × 9.11 × 10^{-31} × v^2 = 0.005 × 10^6 × 1.6 × 10^{-19} seen or equivalent: (0.5 × 9.11 × 10^{-31} × (4.2 × 10^7)^2 giving 0.005 MeV or 4.19 × 10^7 seen [1] Momentum of gamma ray [= $\frac{E}{c}$]= 5.49 × 10^{-22} [N s] [1] Momentum of electron or positron = 9.11 × 10^{-31} × 4.2 × 10^7 = 3.8 × 10^{-23} or 7.6 × 10^{-23} [1] 5.49 × 10^{-22} – 2 × 4.2 × 10^7 × 9.11 × 10^{-31} seen [1]		4		4	3	
	(d)		KE calculated (3.35 × 10^{-19} J or 2.1 eV) [1] Correct conclusion – negligible [1] **No ecf**			2	2	1	
			Question 5 total	**0**	**9**	**2**	**11**	**7**	**0**

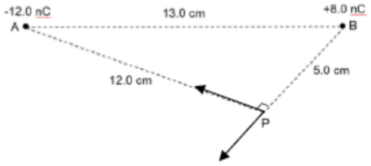
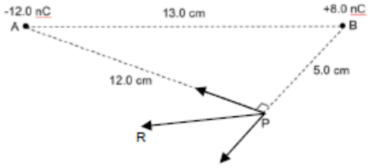
#6

Question			Marking details	AO1	AO2	AO3	Total	Maths	Prac
				Marks available					
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 × 10^6 [J kg^{-1}] [1] Accept answers based on determination of			2	2	1	
	(b)	(i)	Substitution: E_P = 600 × [–] 0.72 × 10^6 [1] E_P = [–] 4.3 × 10^8 [J] [1]	1	1		2	1	
		(ii)	Concept: E_k = -E_P or equivalent [1] Substitution: 4.3 × 10^8 ecf = ½ × 600 × 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**

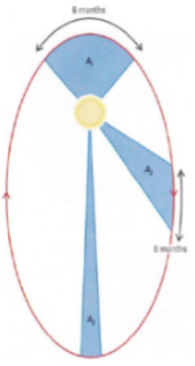
#7

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
3	*(a)*		Use of $s = \frac{1}{2}(u+v)t$ (1) t = 14.6 [s] (1)	1	1		2	2	
	(b)		Gain in KE = 4 020 – 962 = 3 058 [J] (1) Gain in PE = 95 × 9.8 × 4 = 3 728 [J] (1) Total = 3 058 + 3 728 = 6 786 [J] ecf (1)		3		3	3	
	(c)	(i)	Use of $E = VIt$ (1) 3 679 or 3 680 [J] ecf (1)	1	1		2	2	
		(ii)	Useful energy of motor = *(b)* – 6 500 = 1 286 [J] (1) Efficiency $= \frac{1286}{3679} \text{x} 100 = 35$ [%] (1) ecf from (c)(i)		2		2	2	
		(iii)	Friction within motor / between front tyre and road (not just 'friction') (1) Air resistance on bike and Helen (1) Do not accept just heat / sound loss	2			2		
	(d)		Yes compared to petrol vehicles no [direct] emissions (1) ..and power station emissions [of CO_2, PM2s etc] much less than petrol vehicles			2	2		
			Question 3 total	**4**	**7**	**2**	**13**	**9**	**0**

#8

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) = [+] 1 440 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 × 10^{-19} (+540 – 0) (1) **Or** W = - 8.64 × 10^{-17} J seen (accept 540 eV converted into J) Hence gain in E_k = (+) 8.64 × 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 ΔE_k < 0 then opposite answer required.	1	1 1		3		
			Question 7 total	**6**	**10**	**0**	**16**	**7**	**0**

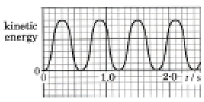
#9

Question			Marking details	AO1	AO2	AO3	Total	Maths	Prac
(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
4	*(a)*			Total energy [of a closed system] stays constant [or equivalent] (1) but energy can be stored [or calculated] in different ways [accept can be converted from one form to another or equivalent] (1).	2			2		
	(b)	(i)	I	Substitution of data from one point on the curved graph or by implication (1) Re-arrangement at any stage of $E = \frac{1}{2}kx^2$ (1) k = 40 N m^{-1} **unit** Accept equivalent unit such as J m^{-2} (1)	1	1 1		3	2	
			II	Substitution of data from one point on straight line or by implication (1) 0.20 kg (1)	1	1		2	1	
			III	Total energy (including at x = 0.050 m) is zero or by implication (1) KE = 0.050 J (1) 'Correct' answer from $\frac{1}{2}mv^2 = \frac{1}{2}kx^2 \rightarrow 0$ marks		2		2	1	
		(ii)		Graph passes through (0, 0), (0.05, 0.05), (0.1, 0) [1] rises and falls smoothly [1]		2		2	2	
	(c)			Attach different masses, m, drop, and measure x_{max} each time (1) Any one relevant experimental detail (e.g. measure x_{max} with metre rule or repeat readings or take precautions against parallax). (1) Plot x_{max} against m [or m against x_{max}] or for each pair of readings calculate $\frac{x_{max}}{m}$ [or $\frac{m}{x_{max}}$] (1) Straight line through origin or constancy of calculated quotient will verify relationship. (1)			4	4	2	4
				Question 4 total	4	7	4	15	8	4

#11

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
5	*(a)*			[Motion such that] acceleration proportional to displacement from a fixed point [1] but in opposite direction or directed towards that point [1] **or** $a = -\omega^2 x$ with a = acceleration and x = displacement [1] ω [or ω^2] constant [1]	2			2		
	(b)	(i)		T = 1.2[0] s (from graph) or by implication [1] Correct re-arrangement $k = \frac{4\pi^2 m}{T^2}$ at any stage **or by impl.** [1] k = 4.80 N m^{-1} **unit mark** [1]		3		3	2	
		(ii)		Correct use of $v_{max} = A\omega$ [= 0.209 m s^{-1}] **or by implic** [1] Correct use of $E_k = \frac{1}{2}mv^2$ **ecf** on slips in v_{max} [1] $E_{k\ max}$ = 3.8 × 10^{-3} J [1]	1 1	1		3	2	
		(iii)		 Zeros at t = 0, 0.6 s, 1.2 s, 1.8 s, 2.4 s [1] KE never negative with equal peaks [1] Smooth (sinusoidal) curve [1]	1 1	1		3	2	
	(c)			Reasonable straight line of best fit drawn [1] Straight line expected as equation equivalent to $\ln A = \ln A_0 - \lambda t$ [1] Some comment about scatter of points – either supporting or casting doubt on straight line [1] λ = –gradient **or by impl.** [1] Gradient calculated correctly e.g. 0.014 [s^{-1}] No *second* penalty for mishandling minus sign [1]			5	5	3	5
				Question 5 total	6	5	5	16	9	5

#12

Question			Marking details	Marks available AO1	AO2	AO3	Total	Maths	Prac
	(a)	(i)	Acceleration = $\frac{0.16}{2.0}$ [=0.08] [m s^{-2}] or by implication (1) Force = 1.2 × [$\frac{0.16}{2.0}$] [N] (**ecf** on acc for this mark only) (1) Force = 0.096 [N] (1) [Deduct only 1 if wrong answer clearly due to arithmetical slip.] **Alternative:** **Don't award individual marks unless overall method clear** s =1.04 [m] (1) v^2-u^2 = 0.166 [m^{2}s^{-2}] **or** ΔE_k = 0.0988 [J] (1) Force = 0.096 [N] (1)	1	1 1		3	3	
		(ii)	Distance = (½)(0.60 + 0.44) × 2.0 [= 1.04 m] **or** equiv **or** by imp (1) Work = 0.096 × [calculated distance] [J] **ecf on (a)(i)** (1) Work = 0.10 [J] (1) **Alternative solution:** Final KE = (½) 1.2 × 0.44^2 [= 0.11616 J] **or** by imp (1) Initial KE = (½) 1.2 × 0.60^2 [= 0.216 J] **or** by imp (1) Work = 0.10 [J] (1)	1	1 1		3	3	
		(iii)	Momentum of system before collision = 1.2 × 0.44 [= 0.528 N s] [or by implic] (1) Momentum of A after collision = –1.2 × 0.14 [= – 0.168 N s] (1) 1.2 × 0.44 = –1.2 × 0.14 + 3.0 v **or** equivalent **or** by implic (1) v = 0.23 [m s^{-1} to the right] (1) Penalty for failure to take account of A's velocity being to the left after collision (gives v = 0.12 [m s^{-1}]) is 2 marks if all else correct. 1 mark penalty for taking A's initial velocity as 0.60 [m s^{-1}]	1 1	1 1		4	4	
		(iv)	Initial KE = (½) 1.2 × 0.44^2 [= 0.116 J] **or** by imp (1) Final KE = (½) 1.2 × 0.14^2 + (½) 3.0 × 0.232^2 [= 0.092 J] **ecf** (1) [KE lost] so inelastic **ecf** (1) **ecf** on A's initial velocity = 0.60 [m s^{-1}]			3	3	2	
	(b)		**3 valid points made - 3rd mark can be a follow-up of one of the points** Examples of 'follow-ups' are preceded by dashes (-) below. Better traction or equivalent May reduce damage to cars in collisions - Metal less likely to deform [under given stress, though stress likely to be greater!] More damage to objects hit by cars May increase damage to passengers during collisions - Thicker metal likely to [decrease collision time and] increase accelerations during collisions Would increase fuel consumption - More energy used to accelerate **or** more energy dissipated in tyres. More metal used [per car] [uses up resources faster] Makes manufacture more difficult Makes cars harder to repair if damaged			3	3		
			Question total	**4**	**6**	**6**	**16**	**12**	**0**