PEARSON EDEXCEL A-LEVEL PHYSICS · 9PH0

PHYSICS



MARK SCHEME

TOPIC 2: MECHANICS

WORK, ENERGY AND POWER

SCORE	PERCENTAGE
/399	%

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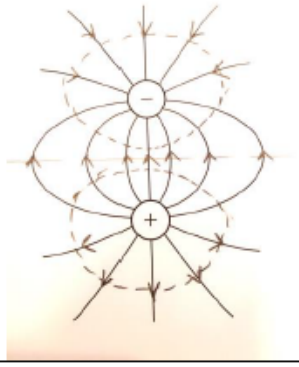
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Mark Scheme

Q1.

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

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

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

Question Number	Acceptable answers	Additional guidance	Mark
(c)	• Use of moment = Fx (1) • Expression for correct moment (1) • 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)	Show that value gives 3.2×10^{-3} Nm and 0.64 W Example of calculation: Moment $= 0.036\text{N}\times0.04\text{m}\times2 = 2.89\times10^{-3}\,\text{Nm}$ Power $= 2.89\times10^{-3}\,\text{N m}\times200\text{s}^{-1} = 0.58\text{W}$	4

Q2.

Question Number	Acceptable Answer	Additional Guidance	
	• Use of $s = \frac{(u+v)}{2}.t$ (1) • Use of $E_k = \frac{1}{2}mv^2$ (1) • Use of $P = \frac{\Delta W}{\Delta t}$ (1) • $P = 110$ W (1)	Example of calculation: $32.5\text{ m} = \frac{(u+0)}{2}\times17.5\text{ s}$ $\therefore u = \frac{32.5\text{ m}\times2}{17.5\text{ s}} = 3.71\text{ m s}^{-1}$ $P = \frac{\Delta E_k}{\Delta t} = \frac{\frac{1}{2}\times19.6\text{ kg}\times(3.7\text{ m s}^{-2})^2}{1.25\text{ s}} = 107\text{ W}$	4

Q3.

Question Number	Acceptable answers	Additional guidance	Mark
(i)	• Use of $\Delta W = F\Delta s$ (1) and $P = W / t$ • Use of $F = ma$ (1) • $a = 0.31$ m s^{-2} (1)	Example of calculation: In 1 second $W = F\Delta s$ 4500 W = $F \times 34$ m s^{-1} Force applied by motor = 132 N $F = ma$ 132 N=420 kg $\times$ a $a = 0.31$ m s^{-2}	3
(ii)	• Neglect friction forces when it starts from rest (1) **Or** Motor/Driving force independent of speed	Do not accept "force" without a description	1

Q4.

Question Number	Acceptable answers	Additional guidance	Mark
	C	*mgh*	1
	A uses the distance AB rather than height B uses a component of height D uses a component of height		

Q5.

Question Number	Acceptable answers	Additional guidance	Mark
(i)	• distance between at least two pairs of images (1) • distances between images are the same in x direction (1) • distance between images varies in y direction showing a changing velocity (1) • velocity in the x direction is constant so x direction is independent of y direction (1)	MP1 and 2 could come from marks on the diagram	4
(ii)	• use of $v^2 = u^2 + 2as$ or $s = ut + \frac{1}{2}at^2$ (1) • initial vertical component velocity = 0.47 m s^{-1} (1) • use of $v_H = d/t$ in the horizontal (1) • Use of Pythagorus with v_H and u_V (1) • Resultant velocity = 1.1 m s^{-1} (1)	alt to MP2 : 0.5 m s^{-1} (allow 0.4 to 0.6) if using distance taken from first two images and $v_H = d/t$ Example of calculation: $0 = u^2 - 2 \times 9.81\ \text{m s}^{-2} \times 0.011\ \text{m}$ $u_V = 0.465\ \text{m s}^{-1}$ $v_H = \frac{0.08\ \text{m}}{0.08\ \text{s}}$ $v_H = 1.0\ \text{m s}^{-1}$ $v = \sqrt{(0.47^2 + 1.0^2)}$ Resultant velocity = 1.1 m s^{-1}	5
(iii)	• Use of $\Delta W = F\ \Delta s$ (1) • Use of $E_k = ½\ mv^2$ (1) • $F = 0.015$ N (1) Alternative • Use of $v^2 = u^2 + 2as$ (1) • Use of $F = ma$ (dependent on MP1) (1) • $F = 0.015$ N (1)	Allow ECF from (a)(ii) Example of calculation: $2 \times F \times 0.003\text{m}$ $= \frac{1}{2} \times 150 \times 10^{-6}\text{kg} \times 1.1^2\ (\text{m s}^{-1})^2$ $F = 0.015$ N "show that" value gives $F = 0.013$ N Alternative $1.1^2\ (\text{ms}^{-1})^2 = 2 \times a \times 0.003\ \text{m}$ $a = 202\ \text{m s}^{-2}$ $2 \times F = 150 \times 10^{-6}\ \text{kg} \times 202\ \text{ms}^{-2}$ $F = 0.015$ N	3

Q6.

Question Number	Acceptable answers	Additional guidance	Mark
	• Uses V = J/C **Or** V = Nm/C **Or** V = Wb s^{-1} **(1)** • Use of T = N/Cms^{-1} **Or** T = N/Am **Or** T = Wb m^{-2} **Or** Sub of $B=F/IL$ and cancels I's **(1)** • Uses units of n = m^{-3} and completes agreement **(1)** Alternative with base units: • Uses base unit of force = kg m s^{-2} **Or** base unit of energy = kg m^2 s^{-2} **(1)** • Uses base unit of charge = A s **Or** uses A = Cs^{-1} **Or** Sub of $B=F/IL$ and cancel I's or A's **(1)** • Uses base units of n = m^{-3} and completes agreement **(1)**	Example of unit simplification: J/C should equal $\frac{N}{Am} \times A \div m^{-3}Cm$ $= \frac{Nm}{C} = \frac{J}{C}$	**(3)**

Q7.

Question Number	Acceptable answers	Additional guidance	Mark
	• Determines vertical height gained per second **(1)** • Use of $\Delta E_{grav} = mg\Delta h$ **(1)** • Use of $\Delta W = F \times \Delta s$ and $P = W/t$ **(1)** • Power = 210 W **(1)** Alternative method based on resolving forces • resolves weight along slope **(1)** • determines total force along the slope **(1)** • Use of $\Delta W = F \times \Delta s$ and $P = W/t$ **(1)** • Power = 210 W **(1)**	Example of calculation P $= 18\ N \times 2.8\ m + 60\ kg \times 9.81\ N\ kg^{-1} \times 2.8m \times \sin 5.7$ $P = 50.4 + 163.7$ $P = 214\ W$ Alternative based on resolving forces $W\sin\theta = 60\ kg \times 9.81\ Nkg^{-1} \times \sin 5.7 = 58.5\ N$ Total force down slope = 58.5 N + 18 N = 76.5 N Power is work done per second = 76.5 N × 2.8 m s^{-1} = 214 W	**4**

Q8.

Question Number	Acceptable Answer	Additional Guidance	Mark
	An explanation that makes reference to the following points: • The potential difference creates an electric field (1) • An (electric) field/force does work on the electrons (increasing their kinetic energy) **Or** an (electric) field/force accelerates the electrons (increasing their velocity) (1)		**2**

Q9.

Question Number	Acceptable answers	Additional guidance	Mark
	• There is (damping due to) air resistance and this (damping) force is the same for both (since they have the same shape, area and speed initially) (1) • For large mass the force due to air resistance produces a smaller negative acceleration since $a = F/m$ (1) • The speed will decrease less for each swing, so there is less effect on the amplitude **Or** It will take longer for the (maximum) speed to decrease (to zero) so the pendulum will oscillate for a longer time (1) **OR** • There is air resistance and the force is the same for both (1) • The work done by air resistance per swing is the same for both masses (1) • Initially the larger mass has greater quantity of energy shared between its kinetic and potential energy stores, so the proportion of KE transferred to the thermal energy store of the sphere and the surroundings is less per swing, so there is less effect on the amplitude **Or** Larger mass has greater total energy so fraction dissipated per swing is smaller so the pendulum will oscillate for a longer time (1)		3

	OR There is air resistance and this force is the same for both (1) • For both masses the change in momentum per swing is the same (1)		

	• The larger mass has greater initial momentum so it will take longer for the (maximum) momentum to decrease (to zero) so the pendulum will oscillate for a longer time (1)		

Q10.

Question Number	Acceptable answers	Additional guidance	Mark
	A		1

Mark Scheme

Q1.

Question Number	Acceptable answers		Additional guidance	Mark
	• Calculates change in mass	(1)	Example of calculation	5
	• Converts from u to kg	(1)	$\Delta m = 238.0003u - (233.9942 + 4.0015)u$	
	• Use of $\Delta E = c^2 \Delta m$	(1)	$= 0.00463 \times 1.66 \times 10^{-27}$ kg	
	• Use of $E_k = ½ mv^2$	(1)	$= 7.636 \times 10^{-30}$ kg	
	• $v = 1.4 \times 10^7$ m s^{-1}		$\Delta E = (3.00 \times 10^8 \text{ m s}^{-1})^2 \times 7.636 \times 10^{-30}$ kg	
			$= 6.872 \times 10^{-13}$ J	
			6.872×10^{-13} J $= ½ (4.0015\ u)\ v^2$	
			$v = 1.4 \times 10^7$ m s^{-1}	

Q2.

Question Number	Acceptable Answer		Additional Guidance	Mark
	• Use of $W = QV$	(1)	Example of calculation:	4
	• Use of $KE = \frac{1}{2}mv^2$	(1)	$\frac{1}{2}mv^2 = eV$	
	• Use of 1u = 1.66 ×10^{-27} kg	(1)	$\therefore v = \sqrt{\frac{2 \times 1.6 \times 10^{-19}\text{C} \times 8.5 \times 10^3\text{V}}{(34.97 \times 1.66 \times 10^{-27})\text{kg}}} = 2.16 \times 10^5 \text{ms}^{-1}$	
	• v = 2.16 × 10^5 (m s^{-1})	(1)		

Q3.

Question Number	Acceptable Answer		Additional Guidance	
	• Use of $s = \frac{(u+v)}{2}.t$	(1)	Example of calculation:	4
	• Use of $E_k = \frac{1}{2}mv^2$	(1)	$32.5 \text{ m} = \frac{(u+0)}{2} \times 17.5 \text{ s}$	
	• Use of $P = \frac{\Delta W}{\Delta t}$	(1)	$\therefore u = \frac{32.5 \text{ m} \times 2}{17.5 \text{ s}} = 3.71 \text{ m s}^{-1}$	
	• $P = 110$ W	(1)	$P = \frac{\Delta E_k}{\Delta t} = \frac{\frac{1}{2} \times 19.6 \text{ kg} \times (3.7 \text{ m s}^{-2})^2}{1.25 \text{ s}} = 107 \text{ W}$	

Q4.

Question Number	Acceptable Answer		Additional Guidance	Mark
(i)	• Use of $F = \frac{GMm}{r^2}$ with $F = \frac{mv^2}{r}$	(1)	Example of calculation: $\frac{GMm}{r^2} = \frac{mv^2}{r}$ $r = \frac{GM}{v^2}$ $r = \frac{6.67\times10^{-11}\text{N m}^2\text{kg}^{-2}\times5.97\times10^{24}\text{ kg}}{(7.59\times10^{3}\text{ m s}^{-1})^2}$ $r=6.91\times10^{6}\text{m}$ $\therefore h=(6.91\times10^{6}-6.37\times10^{6})\text{ m}=5.42\times10^{5}\text{m}$	3
	• Correct substitutions to calculate r	(1)		
	• $h = 5.4\times10^{5}\text{m}$	(1)		
	OR			
	• Use of $g = \frac{GM}{r^2}$ to find value of g at orbit height	(1)		
	• Use of $a = \frac{v^2}{r}$ with value of g at orbit height	(1)		
	• $h = 5.4\times10^{5}\text{m}$	(1)		
(ii)	• Use of $GPE = \frac{GMm}{r}$	(1)	Example of calculation: $GPE = GMm\left(\frac{1}{r_1}-\frac{1}{r_2}\right)$ $\therefore\text{GPE}=6.67\times10^{-11}\text{Nm}^2\text{kg}^{-2}\times5.97\times10^{24}\text{ kg}$ $\times 11600\text{ kg}\left(\frac{1}{6.37\times10^{6}\text{m}}-\frac{1}{6.91\times10^{6}\text{m}}\right)$ $\therefore\text{GPE}=5.67\times10^{10}\text{J}$	2
	• GPE = 5.7×10^{10} J (ecf from (a)(i))	(1)		

Question Number	Acceptable Answer	Additional Guidance	Mark
(iii)	• This would bring the gravitational potential energy closer to zero (1) • This would mean that the satellite would orbit at a greater height as $GPE \propto \frac{1}{r}$ (1) • To remain in orbit the centripetal acceleration must equal the gravitational field strength at the orbit height **Or** Since gravitational force smaller, $\frac{mv^2}{r}$ would be reduced (1) • (Hence) r is greater so v must be smaller **Or** $v^2 = \frac{GM}{r}$ and satellite would orbit at lower speed (1) **OR** • HST will have more kinetic energy at the original orbit height (1) • The centripetal force will be too small to keep it in this orbit (1) • The satellite would be travelling too fast, so it would move to a higher orbit (1) • (Hence) r is greater so v must be smaller **Or** $v^2 = \frac{GM}{r}$ and satellite would orbit at lower speed (1)		4

Q5.

Question Number	Acceptable Answer	Additional guidance	Mark
(a)	• attempts to find area under second peak OR use of a suitable equation of motion OR equate $E = \frac{1}{2}mv^2$ and $\Delta E = mg\Delta h$ (1) • height = 0.9 - 1.0 m (1)	Example of calculation: $h = \frac{1}{2} \times 4.2\ \text{m s}^{-1} \times (1.2-0.70)\ \text{s} = 1.0\ \text{m}$	**(2)**

Question Number	Acceptable Answer	Additional guidance	Mark
(b)	• use of $\Delta E = mg\Delta h$ (1) OR use of $E = \frac{1}{2}mv^2$ (1) • ΔE =0.59 J	Example of calculation: $E = 0.060\ \text{kg} \times 9.81\text{m s}^{-2} \times (2.0 - 1.0)\text{m}$ $E = 0.59\ \text{J}$	**(2)**

Question Number	Acceptable Answer	Additional guidance	Mark
(c)	EITHER • finds gradient of middle section (1) • use of $F = ma$ (1) • $F = 64$ N (1) OR • reads two corresponding pairs of v and t from middle section of graph (1) • use of $F = \frac{m(v-u)}{\Delta t}$ (1) • $F = 64$ N (1)	Example of calculation: $F = \frac{(6.3+4.2)\ \text{m s}^{-1}}{(0.74-0.64)\ \text{s}} \times 0.060\ \text{kg} = 64\ \text{N}$	**(3)**

Question Number	Acceptable Answer	Additional guidance	Mark
(d)	Initial free-fall • gradient of both graphs is the same (1) Bounce section • the gradient of the soft ball graph is less (1) Second free-fall • gradient of the soft ball graph is the same as the first graph OR the gradient is the same as in the initial free-fall (1)	Accept the first line is the same Accept time for the bounce is longer	**(3)**

Q6.

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<tr><th>Question Number</th><th>Acceptable Answer</th><th>Additional Guidance</th><th></th></tr>
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This question assesses a student's ability to show a coherent and logically structured answer with linkages and fully sustained reasoning.

Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.

The table shows how the marks should be awarded for indicative content and lines of reasoning.

<table>
<tr><th>IC points</th><th>IC mark</th><th>Max linkage mark available</th><th>Max final mark</th></tr>
<tr><td>6</td><td>4</td><td>2</td><td>6</td></tr>
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<table>
<tr><th></th><th>Number of marks awarded for structure of answer and sustained line of reasoning</th></tr>
<tr><td>Answer shows a coherent and logical structure with linkage and fully sustained lines of reasoning demonstrated throughout</td><td>2</td></tr>
<tr><td>Answer is partially structured with some linkages and lines of reasoning</td><td>1</td></tr>
<tr><td>Answer has no linkages between its points and is unstructured</td><td>0</td></tr>
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Indicative content:

(Collision takes place on an ice surface so) there is minimal friction Or External forces are negligible
Momentum is conserved in the collision
The momentum of stone A before the collision equals the momentum of (A and) B after the collision
Stone A must be at rest after the collision
All of the kinetic energy of stone A must have been transferred to stone B
Kinetic energy is conserved in an elastic collision

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Q7.

Question number	Acceptable answers	Additional guidance	Mark
(i)	• Use of ½ $mv^2 = mgh$ **(1)** • $v = 2.43$ m s^{-1} **(1)**	Example of calculation: $v = \sqrt{2gh} = \sqrt{2 \times 9.81 \times 0.30} = 2.43$ m s^{-1}	**2**
(ii)	• Use of impulse = change in momentum **(1)** • Recognises initial velocity is zero **(1)** • Hence $F = 0.923$ N **(1)** • Use of $l = \pi d$ **(1)** • Equates calculated value of F with BIl **(1)** • Hence I = 191 A **(1)**	Example of calculation: $Ft = mv - mu$ where $u = 0$ So $F = (0.019 \text{ kg} \times 2.43 \text{ m s}^{-1})/0.05 \text{ s} = 0.923$ N $l = \pi \times 0.048 \text{ m} = 0.151$ m $I = 0.923 \text{ N}/(0.032 \text{ T} \times 0.151 \text{ m}) = 191$ A	**6**

Q8.

Question Number	Answer		Mark
(a)	The wavelength (associated) with a particle/electron with a given momentum **Or** $\lambda = h/p$ all terms defined	(1) (1) (1) (1)	**2**
(b)(i)	Use of $E_k = eV$ Use of $E_k = p^2/2m$ **Or** use of $E_k = mv^2/2$ **and** $p = mv$ Momentum = 1.21×10^{-23} kg m s^{-1} Example of calculation $E_k = 1.6 \times 10^{-19}$ C $\times$ 500 V $p^2 = 2 m E_k = 2 \times 9.11 \times 10^{-31}$ kg $\times$ $(1.6 \times 10^{-19} \times 500)$ J $p = 1.21 \times 10^{-23}$ kg m s^{-1}	(1) (1) (1)	**3**
(b)(ii)	Use of $\lambda = h/p$ $\lambda = 5.49 \times 10^{-11}$ m (ecf value of p from (i)) (show that value gives 6.63×10^{-11} m) Example of calculation $p = 6.63 \times 10^{-34}$ J s / 1.21×10^{-23} kg m s^{-1} $\lambda = 5.49 \times 10^{-11}$ m	(1) (1)	**2**
	Total for question		7

Q9.

Question Number	Acceptable Answer		Additional Guidance	Mark
	• Use of $E_{grav} = mg\Delta h$	(1)	MP1: Use of suvat equation to calculate u	6
	• Use of $E_K = \frac{1}{2}mv^2$ for block and projectile	(1)	MP2: Use of $E_K = \frac{1}{2}mv^2$ for block and projectile **Or** use of $E_{grav} = mg\Delta h$	
	• Use of $p = mv$	(1)	Example of calculation	
	• Use of conservation of momentum	(1)	$E_{grav} = (2.4 + 0.065)\text{kg} \times 9.81\ \text{m s}^{-2} \times 0.55\ \text{m} = 13.3\ \text{J}$ (of block and projectile)	
	• Use of $E_K = \frac{1}{2}mu^2$ for projectile	(1)	$13.3\ \text{J} = \frac{1}{2} \times (2.4 + 0.065)\text{kg} \times v^2$	
	• $\Delta E = 490\ \text{J}$	(1)	$\therefore v = \sqrt{\frac{13.3\ \text{J}}{0.5 \times 2.465\ \text{kg}}} = 3.28\ \text{m s}^{-1}$ $0.065\ \text{kg} \times u = 2.465\ \text{kg} \times 3.28\ \text{m s}^{-1}$ $\therefore u = \frac{8.10\ \text{kg m s}^{-1}}{0.065\ \text{kg}} = 124.6\ \text{m s}^{-1}$ $E_K = \frac{1}{2} \times 0.065\ \text{kg} \times (125\ \text{m s}^{-1})^2 = 504\ \text{J}$ $\therefore \Delta E = (504 - 13.3)\ \text{J} = 491\ \text{J}$	

Q10.

Question Number	Acceptable answers		Additional guidance	Mark
	• Use of $E_K = p^2 / 2m$	(1)	MP1 accept use of $p = mv$ **and** Use of $E_k = ½ mv^2$ MP4 accept (n + ½) λ or n λ respectively Example of calculation $p = \sqrt{(2 \times 9.11 \times 10^{-31}\ \text{kg} \times 9.6 \times 10^{-17}\ \text{J})}$ $p = 1.32 \times 10^{-23}\ \text{kg m s}^{-1}$ $\lambda = 6.63 \times 10^{-34}\ \text{Js} / 1.32 \times 10^{-23}\ \text{kg m s}^{-1}$ $\lambda = 5.0 \times 10^{-11}\ \text{m}$	6
	• Use of $\lambda = h/p$	(1)		
	• $\lambda = 5.0 \times 10^{-11}$ (m) calculated from E_K **Or** $E_K = 9.7 \times 10^{-17}$ (J) calculated fro $\lambda = 5.0 \times 10^{-11}$ m **Or** $p = 1.3 \times 10^{-23}$ (kg m s^{-1}) calculated from E_K **and** $p = 1.3 \times 10^{-23}$ (kg m s^{-1}) calculated from $\lambda = 5.0 \times 10^{-11}$ m	(1)		
	• path difference at X is $\lambda/2$ **Or** path difference at Y is λ	(1)		
	• (electron) <u>waves</u> at X are in antiphase **Or** (electron) <u>waves</u> at Y are in phase	(1)		
	• at X destructive interference/superposition takes place **Or** at Y constructive interference/superposition takes place	(1)		

Q11.

Question Number	Acceptable Answer		Additional Guidance	Mark
	• Use of $E_K = \frac{1}{2}mv^2$	**(1)**	Example of calculation $E_K = \frac{1}{2} \times 1.75\ \text{kg} \times (6.25\ \text{m s}^{-1})^2 = 34.2\ \text{J}$ $\Delta E = 0.65 \times 8000 \times 34.2\ \text{J} = 1.78 \times 10^5\ \text{J}$ $\Delta E = 0.875\ \text{kg} \times 1770\ \text{J kg}^{-1}\text{K}^{-1} \times (165 - 23)\text{K}$ $\therefore \Delta E = 2.20 \times 10^5\ \text{J}$ $E_K = \frac{1}{2} \times 1.75\ \text{kg} \times (6.25\ \text{m s}^{-1})^2 = 34.2\ \text{J}$ $\Delta E = 0.65 \times 34.2\ \text{J} = 22.2\ \text{J}$ $\Delta E = 0.875\ \text{kg} \times 1770\ \text{J kg}^{-1}\text{K}^{-1} \times (165 - 23)\text{K}$ $\therefore \Delta E = 2.20 \times 10^5\ \text{J}$ Number of slaps $= \frac{2.20 \times 10^5\ \text{J}}{22.2\ \text{J}} = 9910$ $E_K = \frac{1}{2} \times 1.75\ \text{kg} \times (6.25\ \text{m s}^{-1})^2 = 34.2\ \text{J}$ $\Delta E = 0.65 \times 8000 \times 34.2\ \text{J} = 1.78 \times 10^5\ \text{J}$ $1.78 \times 10^5\text{J} = 0.875\ \text{kg} \times 1770\ \text{J kg}^{-1}\text{K}^{-1} \times (T_f - 296)\text{K}$ $\therefore T_f = \frac{1.78 \times 10^5\ \text{J}}{1.55 \times 10^3\ \text{J K}^{-1}} + 296\ \text{K} = 411\ \text{K}$ $\therefore \theta_f = (411 - 273)\ \text{K} = 138\ ^\circ\text{C}$ MP5: must see a correct value as part of the conclusion	**5**
	• Use of $\Delta E = mc\Delta\theta$	**(1)**		
	• Use of 8000 **Or** use of (energy required) / (energy per slap)	**(1)**		
	• Use of 65% with input energy	**(1)**		
	• Energy from 8000 slaps would be 1.78×10^5 J which is less than the energy required to raise the temperature to 165 °C (2.20×10^5 J) **Or** final temperature would be 138 °C, so not enough **Or** 9900 slaps would be needed, so not enough **Or** temperature rise from 8000 slaps is 115 K which is less than required temperature rise of 142 K	**(1)**		

Q12.

Question Number	Acceptable answers	Additional guidance	Mark
(i)	• distance between at least two pairs of images (1) • distances between images are the same in x direction (1) • distance between images varies in y direction showing a changing velocity (1) • velocity in the x direction is constant so x direction is independent of y direction (1)	MP1 and 2 could come from marks on the diagram	4
(ii)	• use of $v^2 = u^2 + 2as$ or $s = ut + \frac{1}{2}at^2$ (1) • initial vertical component velocity = 0.47 m s^{-1} (1) • use of $v_H = d/t$ in the horizontal (1) • Use of Pythagorus with v_H and u_V (1) • Resultant velocity = 1.1 m s^{-1} (1)	alt to MP2 : 0.5 m s^{-1} (allow 0.4 to 0.6) if using distance taken from first two images and $v_H = d/t$ Example of calculation: $0 = u^2 - 2 \times 9.81\ \text{m s}^{-2} \times 0.011\ \text{m}$ $u_V = 0.465\ \text{m s}^{-1}$ $v_H = \frac{0.08\ \text{m}}{0.08\ \text{s}}$ $v_H = 1.0\ \text{m s}^{-1}$ $v = \sqrt{(0.47^2 + 1.0^2)}$ Resultant velocity = 1.1 m s^{-1}	5
(iii)	• Use of $\Delta W = F\ \Delta s$ (1) • Use of $E_k = ½\ mv^2$ (1) • $F = 0.015$ N (1) Alternative • Use of $v^2 = u^2 + 2as$ (1) • Use of $F = ma$ (dependent on MP1) (1) • $F = 0.015$ N (1)	Allow ECF from (a)(ii) Example of calculation: $2 \times F \times 0.003\text{m}$ $= \frac{1}{2} \times 150 \times 10^{-6}\text{kg} \times 1.1^2\ (\text{m s}^{-1})^2$ $F = 0.015$ N "show that" value gives $F = 0.013$ N Alternative $1.1^2\ (\text{ms}^{-1})^2 = 2 \times a \times 0.003\ \text{m}$ $a = 202\ \text{m s}^{-2}$ $2 \times F = 150 \times 10^{-6}\ \text{kg} \times 202\ \text{ms}^{-2}$ $F = 0.015$ N	3

Q13.

Question Number	Acceptable answers		Additional guidance	Mark
(i)	• Use of $V = -Gm / r$ • Change in $V = 3.18 \times 10^{13}$ (J kg^{-1})	(1) (1)	Example of calculation $\Delta V = -Gm\ (1/r_2 - 1/r_1)$ $= -6.67 \times 10^{-11}$ N m^2 kg^{-2} $\times$ 9.2×10^{36} kg $\times$ $((1/2.7 \times 10^{14}$ m $- 1/1.8 \times 10^{13}$ m) $= 3.18 \times 10^{13}$ J kg^{-1}	2
(ii)	• Equate change in gravitational potential energy to change in kinetic energy **Or** use of $E_p = mV$ • Use of $E_k = ½\ mv^2$ • $v = 1.4 \times 10^6$ m s^{-1}	(1) (1) (1)	Example of calculation $m \times 3.18 \times 10^{13}$ J kg^{-1} $= (0.5 \times m \times (8.10 \times 10^6$ m s$^{-1})^2) - (0.5 \times m\ v_2^2)$ $v_2 = 1.4 \times 10^6$ m s^{-1}	3

Q14.

Question Number	Acceptable Answer		Additional Guidance	Mark
	• Speed of impact is the same for both spheres • mass of sphere $\propto$ (diameter)^3 • $E_k = \frac{1}{2}mv^2$ so factor $= 8$ **OR** • Final $E_k = \Delta E_{grav}$ • mass of sphere $\propto$ (diameter)^3 • $\Delta E_{grav} = mg\Delta h$, so factor $= 8$	(1) (1) (1) (1) (1) (1)	For MP2 accept radius instead of diameter A bald correct answer scores MP3 only Example of calculation: $\frac{m_2}{m_1} = \left(\frac{4\text{ cm}}{2\text{ cm}}\right)^3 = 8$ $\frac{E_{k2}}{E_{k1}} = \frac{m_2}{m_1} = 8$	3

Q15.

Question Number	Acceptable Answer		Additional Guidance	Mark
	• Cross sectional area $\times$ length used to calculate volume • Use of $E_k = \frac{1}{2}mv^2$ • Energy per unit volume $= 1.7 \times 10^8$ (J m^{-3})	(1) (1) (1)	Example of calculation: Volume of seatbelt, $V = 0.85 \times 10^{-4}$ m$^2 \times 2$ m $V = 1.7 \times 10{-}4$ m^3 $E_k = \frac{1}{2} \times 75\text{ kg} \times (28\text{ m s}^{-1})^2 = 2.9 \times 10^4$ J $\therefore \frac{E}{V} = \frac{2.9 \times 10^4 \text{J}}{1.7 \times 10^{-4}\text{ m}^3} = 1.73 \times 10^8$ J m^{-3}:	3

Q16.

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	• Use of $F = BQv$ and $F = EQ$ (1) • Algebra to show $v = \frac{E}{B}$ (1)		2
(ii)	• Use of $W = QV$ *and* $E_k = \frac{1}{2}mv^2$ (1) • Use of $v = \frac{E}{B}$ (1) • $\frac{e}{m} = 1.7 \times 10^{11}$ C kg^{-1} (1)	Example of calculation: $v = \frac{E}{B} = \frac{1.4 \times 10^4 \text{ V m}^{-1}}{1.5 \times 10^{-3} \text{ T}}$ $\frac{e}{m} = \frac{v^2}{2V}$ $\frac{e}{m} = \frac{\left(9.33 \times 10^6 \text{ m s}^{-1}\right)^2}{2 \times 250 \text{ V}} = 1.74 \times 10^{11}$ C kg^{-1}	3

Q17.

Question Number	Acceptable Answer	Additional Guidance	Mark
	An explanation that makes reference to the following points: • $v_{max} = \omega A$ and ω constant (1) • If A doubles, then v_{max} doubles (1) • Hence max E_k will quadruple, since $E_k = \frac{1}{2}mv^2$ [dependent upon MP2] (1) OR • $\Delta E_{el} = \frac{1}{2}F\Delta x$ **and** $\Delta F = k\Delta x$ (1) • $\Delta E_{el} \propto (\Delta x)^2$ since k is constant (1) • Hence max E_k will quadruple, since max E_k = max ΔE_{el} (dependent upon MP2) (1)		3

Q18.

Question Number	Acceptable answers	Additional guidance	Mark
	• Use of $V_{grav} = -GM/R$ (1) • Calculate $\Delta V_{grav} = V_{grav\ Moon} - V_{grav\ Earth}$ (1) • Use of $m\ \Delta V_{grav} = E_k = ½\ mv^2$ (1) • $v = 11\ 000\ m\ s^{-1}$ (1)	Example of calculation $V_{grav} = -6.67 \times 10^{-11}\ N\ m^2\ kg^{-2} \times 5.97 \times 10^{24}\ kg\ /$ $6\ 370\ 000\ m = -62.5\ MJ\ kg^{-1}$ $\Delta V_{grav} = -62.5\ MJ\ kg^{-1} - -1.28\ MJ\ kg^{-1}$ $= -61.2\ MJ\ kg^{-1}$ $½\ v^2 = 61.2\ MJ\ kg^{-1}$ $v = 11\ 100\ m\ s^{-1}$	4

Q19.

Question Number	Acceptable Answer	Additional Guidance	Mark
*	This question assesses a student's ability to show a coherent and logically structured answer with linkages and fully sustained reasoning. Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning. The table shows how the marks should be awarded for indicative content and lines of reasoning. **IC points / IC mark / Max linkage mark available / Max final mark** 6 / 4 / 2 / 6 5 / 3 / 2 / 5 4 / 3 / 1 / 4 3 / 2 / 1 / 3 2 / 2 / 0 / 2 1 / 1 / 0 / 1 0 / 0 / 0 / 0 Indicative content: • The table shows that increasing the drop height does increase the crater diameter • Increasing the drop height increases the impact velocity/E_k • Because there is a greater acceleration time **Or** because there is a greater transfer of GPE to KE • The table does not show that increasing the sphere diameter (always) increases the crater diameter • For smaller spheres (from 2 to 4 cm), increasing sphere diameter does increase crater diameter **Or** for bigger spheres (from 4 to 6 cm), increasing the sphere diameter has little effect on crater diameter • More data is needed for firmer conclusions	 **Number of marks awarded for structure of answer and sustained line of reasoning** Answer shows a coherent and logical structure with linkage and fully sustained lines of reasoning demonstrated throughout: 2 Answer is partially structured with some linkages and lines of reasoning: 1 Answer has no linkages between its points and is unstructured: 0 For IC3 accept reference to an appropriate equation For IC5 accept "no effect" or "inconsistent effect" for "little effect"	6

Q20.

Question Number	Acceptable answers		Additional guidance	Mark
	• Use of energy conservation	(1)	Example of calculation: $\frac{1}{2}mv^2_{\text{top}} + mgh = \frac{1}{2}mv^2_{\text{bottom}}$ $g(\text{ms}^{-2})r(\text{m}) + 2g(\text{ms}^{-2})0.30(\text{m}) = v^2(\text{ms}^{-1})^2$ $v^2 = 0.75g$ $v = 2.71\text{ms}^{-1}$	(3)
	• Substitution of $v^2 = rg$	(1)		
	• $V_{\text{bottom}} = 2.7\ \text{m s}^{-1}$	(1)		

Q21.

Question Number	Acceptable Answer	Additional Guidance	Mark
(a)	An explanation that makes reference to the following: • air molecules make collisions with the puck and transfer momentum to the puck (1) • according to Newton's 2nd law the change of momentum creates a force on the puck (1) • the rate of change of momentum by air molecules colliding with bottom of puck is greater than that due to the collisions on the top of the puck (1) • the net (upward) force balances the weight of the puck <u>OR</u> the greater air pressure below the puck allows the puck to be supported. (1)		**(4)**

<table>
<tr><th>Question Number</th><th>Acceptable Answer</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr><td>* (b)</td><td>This question assesses a student's ability to show a coherent and logically structured answer with linkages and fully-sustained reasoning.

Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.

The following table shows how the marks should be awarded for indicative content.

<table><tr><th>Number of indicative marking points seen in answer</th><th>Number of marks awarded for indicative marking points</th></tr><tr><td>6</td><td>4</td></tr></table></td><td>Guidance on how the mark scheme should be applied: The mark for indicative content should be added to the mark for lines of reasoning. For example, an answer with five indicative marking points which is partially structured with some linkages and lines of reasoning scores 4 marks (3 marks for indicative content and 1 mark for partial structure and some linkages and lines of reasoning). If there are no linkages between points, the same five indicative marking points would yield an overall score of 3 marks (3 marks for indicative content and no marks for linkages).</td><td></td></tr>
</table>

5 - 4	3
3 - 2	2
1	1
0	0

The following table shows how the marks should be awarded for structure and lines of reasoning.

	Number of marks awarded for structure of answer and sustained line of reasoning
Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout	2
Answer is partially structured with some linkages and lines of reasoning	1
Answer has no linkages between points and is unstructured	0

Indicative content:

- applying Newton's 3rd law one puck (A) exerts a force on the other puck (B) and vice versa (1)
- forces equal in magnitude and opposite and direction (1)
- forces act for same time (1)
- $F\Delta t_A = -F\Delta t_B$ (1)
- applying Newton's 2nd law $F\Delta t = \Delta p$ since F is a resultant force on each puck (1)
- total change in momentum = zero, so momentum is conserved (1)
  OR Δp for one puck = $-\Delta p$ for the other puck, so momentum is conserved

(6)

Question Number	Acceptable Answer		Additional Guidance	Mark
(c)(i)	• resolve velocities to find forward/sideways component	(1)	Example of calculation: Forwards velocity components: $v\cos 30^\circ = 0.866\,v$; $2\cos 60^\circ = 1\,\text{m s}^{-1}$ $4m = m \times 0.866v + m \times 1$ $\therefore v = \frac{(4-1)\,\text{m s}^{-1}}{0.866} = 3.46\,\text{m s}^{-1}$	**(3)**
	• apply principle of conservation of momentum	(1)		
	• v = 3.46 m s^{-1}	(1)		
(c)(ii)	• use $KE = \frac{1}{2}mv^2$	(1)	Example of calculation: $KE_i = \frac{1}{2}m \times 4^2 = 8m$ $KE_f = \frac{1}{2}m \times 3.46^2 + \frac{1}{2}m \times 2^2$ $= 6m + 2m = 8m$	**(3)**
	• show that final KE is equal to initial KE	(1)		
	• elastic collisions conserve KE, so collision is elastic	(1)		

Q22.

Question Number	Acceptable answers	Additional guidance	Mark
	The only correct answer is B *A is not correct because this is not dimensionally correct* *C is not correct because* $E_k/2p = v/4$ *D is not correct because this is not dimensionally correct*		**1**

Q23.

Question Number	Answer	Mark
	A	1

Q24.

Question Number	Acceptable answers		Additional guidance	Mark
(i)	• Use of momentum = mv	(1)	Example of calculation: $7.1(g)u = 7.1(g) \times 0.9(ms^{-1}) \times cos\,8 + 3.6(g) \times 1.4(ms^{-1}) \times cos\,10$ $u = \frac{(6.33 + 4.96)}{7.1}$ $u = 1.59 ms^{-1}$	(4)
	• See component(s) in x direction	(1)		
	• Uses momentum conservation	(1)		
	• u = 1.6 (m s^{-1})	(1)		

Question Number	Acceptable answers		Additional guidance	Mark
(ii)	• Use of $E_k = ½ mv^2$	(1)	Allow ecf from b(i) Example of calculation: Initial E_k = ½ ×7.1×10^{-3}(kg)×1.59^2(ms^{-1})^2 = 9.0×10^{-3} J Final E_k = ½ ×7.1×10^{-3} × 0.9^2 + ½ ×3.6×10^{-3} ×1.4^2 = 6.4×10^{-3} J	(2)
	• Value of Initial E_k = 9.0×10^{-3} (J) and Final E_k = 6.4×10^{-3} (J) (Show that value gives Initial E_k = 1.42 ×10^{-2} (J) allow ecf from (b)(i))	(1)		

Q25.

Question Number	Acceptable Answers		Additional Guidance	Mark
	• Use of $V_{grav} = -GM/r$ **Or** Use of $E_P = -GMm/r$ with an assumed mass	(1)	Example of calculation $\Delta V = 6.67 \times 10^{-11}$ N m^2 kg^{-2} × 3.30 × 10^{23} kg (1/2.43 × 10^6 m – 1/1.743 × 10^7 m) = 7.795 × 10^6 J kg^{-1} ½ mv^2 = 7.795 × 10^6 J kg^{-1} × m Assume 1 kg v = 3948 m s^{-1}	4
	• Subtraction of potential at surface from potential at orbital height **Or** Subtraction of potential energy at surface from potential energy at orbital height	(1)		
	• Use of difference in potential = E_K/m = ½ v^2 **Or** Use of difference in potential energy = E_K = ½ mv^2	(1)		
	• v = 3948 m s^{-1}	(1)		

Mark Scheme

Q1.

Question number	Acceptable answers	Additional guidance	Mark
(i)	• Recognise that for passenger to remain in their seat normal reaction $R \geq 0$ **(1)** **or** centripetal force >= weight **(1)** • Equate centripetal force and weight (for R=0) **(1)** • $v = 9.1\ \text{m s}^{-1}$ **(1)**	Example of calculation: $\frac{mv^2}{r} = mg$ $v = \sqrt{rg} = \sqrt{8.5\,\text{m} \times 9.81\,\text{m s}^{-2}} = 9.13\,\text{m s}^{-1}$	**3**
(ii)	• Equate decrease in gravitational potential energy to increase in kinetic energy at top of loop **(1)** • Adds this to 17.0 **(1)** • $\Delta h = 21.3$ m **(1)**	Example of calculation: $mgh = \frac{1}{2}mv^2$ $h = \frac{v^2}{2g} = \frac{(9.13\,\text{m s}^{-1})^2}{2 \times 9.81\,\text{m s}^{-2}} = 4.25\,\text{m}$ $\Delta h = 17 + 4.3 = 21.3$ m	**3**

Q2.

Question Number	Acceptable Answer	Additional guidance	Mark
(a)	• attempts to find area under second peak (1) OR use of a suitable equation of motion OR equate $E = \frac{1}{2}mv^2$ and $\Delta E = mg\Delta h$ • height = 0.9 - 1.0 m (1)	Example of calculation: $h = \frac{1}{2} \times 4.2\,\text{m s}^{-1} \times (1.2 - 0.70)\,\text{s} = 1.0$ m	**(2)**

Question Number	Acceptable Answer	Additional guidance	Mark
(b)	• use of $\Delta E = mg\Delta h$ (1) OR use of $E = \frac{1}{2}mv^2$ (1) • ΔE =0.59 J	Example of calculation: $E = 0.060\,\text{kg} \times 9.81\,\text{m s}^{-2} \times (2.0 - 1.0)\,\text{m}$ $E = 0.59$ J	**(2)**

Question Number	Acceptable Answer	Additional guidance	Mark
(c)	EITHER • finds gradient of middle section (1) • use of $F = ma$ (1) • $F = 64$ N (1) OR • reads two corresponding pairs of v and t from middle section of graph (1) • use of $F = \frac{m(v-u)}{\Delta t}$ (1) • $F = 64$ N (1)	Example of calculation: $F = \frac{(6.3+4.2)\ \text{m s}^{-1}}{(0.74-0.64)\ \text{s}} \times 0.060\ \text{kg} = 64\ \text{N}$	**(3)**

Question Number	Acceptable Answer	Additional guidance	Mark
(d)	Initial free-fall • gradient of both graphs is the same (1) Bounce section • the gradient of the soft ball graph is less (1) Second free-fall • gradient of the soft ball graph is the same as the first graph OR the gradient is the same as in the initial free-fall (1)	Accept the first line is the same Accept time for the bounce is longer	**(3)**

Q3.

Question number	Acceptable answers	Additional guidance	Mark
(i)	• Use of ½ $mv^2 = mgh$ **(1)** • $v = 2.43$ m s^{-1} **(1)**	Example of calculation: $v = \sqrt{2gh} = \sqrt{2 \times 9.81 \times 0.30} = 2.43$ m s^{-1}	**2**
(ii)	• Use of impulse = change in momentum **(1)** • Recognises initial velocity is zero **(1)** • Hence $F = 0.923$ N **(1)** • Use of $l = \pi d$ **(1)** • Equates calculated value of F with BIl **(1)** • Hence I = 191 A **(1)**	Example of calculation: $Ft = mv - mu$ where $u = 0$ So $F = (0.019 \text{ kg} \times 2.43 \text{ m s}^{-1})/0.05 \text{ s} = 0.923$ N $l = \pi \times 0.048 \text{ m} = 0.151$ m $I = 0.923 \text{ N}/(0.032 \text{ T} \times 0.151 \text{ m}) = 191$ A	**6**

Q4.

Question Number	Acceptable Answer	Additional guidance	Mark
(a)	• use of $T = \frac{2\pi}{w}$ (1) • 1.7x10^{-3} rad s^{-1} or $\frac{\pi}{1800}$ rad s^{-1} (1)	Example of calculation: $w = \frac{2\pi}{(60 \times 60) \text{ s}}$	**(2)**

Question Number	Acceptable Answer	Additional guidance	Mark
(b)	• recognises weight acts halfway along hand (1) • uses correct angle between the two positions (1) • determines change in vertical height (= 0.008 m) (1) • use of $\Delta E = mg\Delta h$ (1) • work done = 1.1 (mJ) (1)	Example of calculation: $W = 0.014 \text{ kg} \times 9.81 \text{ N kg}^{-1} \times (2 \times 0.04 \sin 6^\circ \text{ m})$ $W = 1.1 \times 10^{-3}$ J	**(5)**

Question Number	Acceptable Answer	Additional guidance	Mark
(c)	• use of $P = VI$ (1) • use of $P = \frac{W}{t}$ (1) AND 65% • t = 141 s (1)	Example of calculation: $P = 1.5\ \text{V} \times 8.0 \times 10^{-6}\ \text{A} = 1.2 \times 10^{-5}\ \text{W}$ $t = \frac{1.1 \times 10^{-3}\ \text{J}}{0.65 \times 1.2 \times 10^{-5}\ \text{W}} = 141\ \text{s}$	**(3)**

Q5.

Question Number	Acceptable Answer	Additional Guidance	Mark
	• Use of $E_{\text{grav}} = mg\Delta h$ (1) • Use of $E_{\text{K}} = \frac{1}{2}mv^2$ for block and projectile (1) • Use of $p = mv$ (1) • Use of conservation of momentum (1) • Use of $E_{\text{K}} = \frac{1}{2}mu^2$ for projectile (1) • $\Delta E = 490\ \text{J}$ (1)	MP1: Use of suvat equation to calculate u MP2: Use of $E_{\text{K}} = \frac{1}{2}mv^2$ for block and projectile **Or** use of $E_{\text{grav}} = mg\Delta h$ Example of calculation $E_{\text{grav}} = (2.4 + 0.065)\text{kg} \times 9.81\ \text{m s}^{-2} \times 0.55\ \text{m} = 13.3\ \text{J}$ (of block and projectile) $13.3\ \text{J} = \frac{1}{2} \times (2.4 + 0.065)\text{kg} \times v^2$ $\therefore v = \sqrt{\frac{13.3\ \text{J}}{0.5 \times 2.465\ \text{kg}}} = 3.28\ \text{m s}^{-1}$ $0.065\ \text{kg} \times u = 2.465\ \text{kg} \times 3.28\ \text{m s}^{-1}$ $\therefore u = \frac{8.10\ \text{kg m s}^{-1}}{0.065\ \text{kg}} = 124.6\ \text{m s}^{-1}$ $E_{\text{K}} = \frac{1}{2} \times 0.065\ \text{kg} \times (125\ \text{m s}^{-1})^2 = 504\ \text{J}$ $\therefore \Delta E = (504 - 13.3)\ \text{J} = 491\ \text{J}$	6

Q6.

Question Number	Acceptable answers	Additional guidance	Mark
	• Use of $\Delta E_{grav} = mg\Delta h$ (1) • convert for a unit time, e.g. day or second ie W (1) • Calculation of energy input provided by coal in unit time (1) • Use of Efficiency = energy output/energy input (1) **Or** in terms of power • Efficiency = 1.5 % so not correct (1)	(allow reverse argument starting with 10% efficiency for full credit) Example of calculation: $\Delta E_{grav} = 2500 \times 9.81 \times 12$ $\Delta E_{grav} = 294\text{kJ per minute}$ $\Delta E_{grav} = 294\text{kJ} \times 60 \times 24$ $\Delta E_{grav} = 424\text{MJ per day}$ energy input = 1250 × 22.3 MJ Efficiency = 424 MJ/ 27900 MJ = 1.5%	5

Q7.

Question Number	Acceptable answers	Additional guidance	Mark
	Max 2 • normal car would have much more mass (1) • too much area of solar cell needed so impractical (1) • going uphill would need far more power (1)		2

Q8.

Question Number	Acceptable answers	Additional guidance	Mark
	C	*mgh*	1
	A uses the distance AB rather than height B uses a component of height D uses a component of height		

Q9.

Question Number	Acceptable answers	Additional guidance	Mark
	• The curved surface is (analogous to) a radial field **(1)** • (as $h \propto {}^{1}/_{r}$ then) potential (energy) $\propto {}^{1}/_{r}$ **(1)** • compares with $V \propto {}^{1}/_{r}$ around a point charge **(1)**		**3**

Q10.

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<tr><td>2</td><td>2</td><td>0</td><td>2</td></tr>
<tr><td>1</td><td>1</td><td>0</td><td>1</td></tr>
<tr><td>0</td><td>0</td><td>0</td><td>0</td></tr>
</table>
Indicative content:

The table shows that increasing the drop height does increase the crater diameter
Increasing the drop height increases the impact velocity/E_k
Because there is a greater acceleration time
Or because there is a greater transfer of GPE to KE
The table does not show that increasing the sphere diameter (always) increases the crater diameter
For smaller spheres (from 2 to 4 cm), increasing sphere diameter does increase crater diameter Or for bigger spheres (from 4 to 6 cm), increasing the sphere diameter has little effect on crater diameter
More data is needed for firmer conclusions

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<tr><td>Answer has no linkages between its points and is unstructured</td><td>0</td></tr>
</table>
For IC3 accept reference to an appropriate equation

For IC5 accept "no effect" or "inconsistent effect" for "little effect"
</td>
<td>6</td>
</tr>
</table>

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Mark Scheme

Q1.

Question number	Acceptable answers	Additional guidance	Mark
(i)	• Recognise that for passenger to remain in their seat normal reaction $R \geq 0$ **(1)** **or** centripetal force >= weight **(1)** • Equate centripetal force and weight (for R=0) **(1)** • $v = 9.1\ \text{m s}^{-1}$ **(1)**	Example of calculation: $\frac{mv^2}{r} = mg$ $v = \sqrt{rg} = \sqrt{8.5\,\text{m} \times 9.81\,\text{m s}^{-2}} = 9.13\,\text{m s}^{-1}$	**3**
(ii)	• Equate decrease in gravitational potential energy to increase in kinetic energy at top of loop **(1)** • Adds this to 17.0 **(1)** • $\Delta h = 21.3$ m **(1)**	Example of calculation: $mgh = \frac{1}{2}mv^2$ $h = \frac{v^2}{2g} = \frac{(9.13\,\text{m s}^{-1})^2}{2 \times 9.81\,\text{m s}^{-2}} = 4.25\,\text{m}$ $\Delta h = 17 + 4.3 = 21.3$ m	**3**

Q2.

Question number	Acceptable answers	Additional guidance	Mark
(i)	• Use of ½ $mv^2 = mgh$ **(1)** • $v = 2.43$ m s^{-1} **(1)**	Example of calculation: $v = \sqrt{2gh} = \sqrt{2 \times 9.81 \times 0.30} = 2.43$ m s^{-1}	**2**
(ii)	• Use of impulse = change in momentum **(1)** • Recognises initial velocity is zero **(1)** • Hence $F = 0.923$ N **(1)** • Use of $l = \pi d$ **(1)** • Equates calculated value of F with BIl **(1)** • Hence I = 191 A **(1)**	Example of calculation: $Ft = mv - mu$ where $u = 0$ So $F = (0.019 \text{ kg} \times 2.43 \text{ m s}^{-1})/0.05 \text{ s} = 0.923$ N $l = \pi \times 0.048 \text{ m} = 0.151$ m $I = 0.923 \text{ N}/(0.032 \text{ T} \times 0.151 \text{ m}) = 191$ A	**6**

Q3.

Question Number	Acceptable Answer	Additional Guidance	Mark
	• There is no way to insulate the chicken from the surroundings **Or** there will be energy transfer if there is a temperature difference with the surroundings **Or** there will be energy transfer unless the chicken is in thermal equilibrium with the surroundings **Or** energy will be transferred to the surroundings between slaps **Or** it would take a long time for 8000 slaps so there will be energy transfer **(1)** • So the assumption is unrealistic (dependent mark) **(1)**	MP1: accept lag	**2**

Q4.

Question Number	Acceptable answers	Additional guidance	Mark
	C	*mgh*	**1**
	A uses the distance AB rather than height B uses a component of height D uses a component of height		

Q5.

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	• (Use the stopwatch to) time a large number of oscillations to determine the time period **(1)** • Calculate the frequency using $f = \frac{1}{T}$ **(1)**	MP1: At least 5 oscillations required	**2**
(ii)	• (Use the metre rule to) measure the max displacement of the platform (from the equilibrium position) **(1)** • Calculate the maximum speed using $v_{max} = 2\pi f x_{max}$ **(1)**	MP2: allow use of $v_{max} = \frac{2\pi}{T} x_{max}$	**2**

Q6.

Question Number	Acceptable Answer	Additional Guidance	Mark
	• Total energy is constant, but kinetic energy decreases **Or** reference to an inelastic collision **(1)** • Projectile does work on block **Or** internal energy of block increases **(1)**		**2**

Q7.

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	An explanation that makes reference to the following: • To bring tubing up to temperature (of steam) (1) • So steam only condenses in the cup (1) **Or** steam doesn't condense in the tubing		2
(ii)	• Thermal energy will be transferred from the steam/tubing to the surroundings (1) • Lagging/insulating/shortening the tubing (1)	Accept: • Thermal energy is transferred to the cup/ probe • These should have a small a heat capacity	2

Q8.

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	• Change in temperature and corresponding time (1) • Use of $P = \Delta E/\Delta t$ and $\Delta E = mc\Delta\theta$ (1) • $c = 950\ \text{J kg}^{-1}\ \text{K}^{-1}$ (1)	Example of calculation: $\frac{\Delta\theta}{\Delta t} = \frac{(36 - 16)\ \text{K}}{(500 - 0)\ \text{s}} = 0.04\ \text{K s}^{-1}$ $37.5\ \text{W} = 0.986\ \text{kg} \times c \times 0.04\ \text{K s}^{-1}$ $c = 951\ \text{J kg}^{-1}\ \text{K}^{-1}$	3
(ii)	An explanation that makes reference to the following points: • In 240 s the temperature of the block rose by only 9.6 °C **Or** It took 250 s for the temperature of the block to rise by 10 °C. (1) • Hence there must have been energy transfer to the surroundings (by heating) (1)	For MP1 accept 9.5 °C Accept it took 10 s longer For MP2 accept energy dissipated to the surroundings	2

Q9.

Question Number	Acceptable answers	Additional guidance	Mark
	• There is (damping due to) air resistance and this (damping) force is the same for both (since they have the same shape, area and speed initially) (1) • For large mass the force due to air resistance produces a smaller negative acceleration since $a = F/m$ (1) • The speed will decrease less for each swing, so there is less effect on the amplitude **Or** It will take longer for the (maximum) speed to decrease (to zero) so the pendulum will oscillate for a longer time (1) **OR** • There is air resistance and the force is the same for both (1) • The work done by air resistance per swing is the same for both masses (1) • Initially the larger mass has greater quantity of energy shared between its kinetic and potential energy stores, so the proportion of KE transferred to the thermal energy store of the sphere and the surroundings is less per swing, so there is less effect on the amplitude **Or** Larger mass has greater total energy so fraction dissipated per swing is smaller so the pendulum will oscillate for a longer time (1)		3

	OR There is air resistance and this force is the same for both (1) • For both masses the change in momentum per swing is the same (1)		

	• The larger mass has greater initial momentum so it will take longer for the (maximum) momentum to decrease (to zero) so the pendulum will oscillate for a longer time (1)		

Q10.

Question Number	Acceptable answers	Additional guidance	Mark
	• Work done (by cyclist) results in a <u>transfer</u> of energy **(1)** • initially there is an increase in E_k of (cyclist and bicycle) **Or** work done is transferred/converted to other forms of energy **(1)** • when the velocity of the cyclist is constant, all the energy is being transferred to other forms **(1)**		**3**

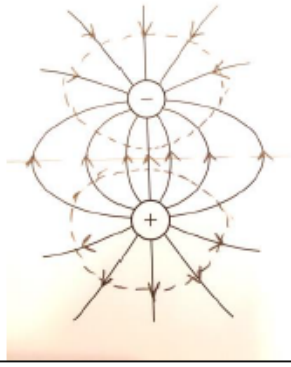
Mark Scheme

Q1.

Question Number	Acceptable answers	Additional guidance	Mark
	• Use of $\Delta E = mc\Delta\theta$ (1) • Use of $\Delta E = L\Delta m$ (1) • Apply 5% to calculate energy saved (1) • Use of $P = VI$ or Use of $Q = It$ (1) • Use of $P = \frac{W}{t}$ or Use of $E = QV$ (1) • 2.69×10^5 J compared with 1.93×10^5 J for energy saved, and concludes claim invalid. (1) **Or** a phone could run for 5 days compared to 7 days and conclusion claim invalid **Or** a phone could run for 433 900 s compared to 604 800 s and conclusion claim invalid	Example of calculation: For aluminium when being heated up to m.pt.: $\Delta E = 14 \times 10^{-3}\ \text{kg} \times 902\ \text{J kg}^{-1}\text{K}^{-1} \times (660 - 293)\text{K}$ $\Delta E = 4.63 \times 10^3\ \text{J}$ For aluminium when melting: $\Delta E = 14 \times 10^{-3}\ \text{kg} \times 396 \times 10^3\ \text{J kg}^{-1} = 5.54 \times 10^3\ \text{J}$ Energy saved $= \frac{0.95}{0.05} \times (4630 + 5540)\text{J}$ Energy saved $= 1.93 \times 10^5\ \text{J}$ $P = 3.7\ \text{V} \times 120 \times 10^{-3}\ \text{A} = 0.444\ \text{W}$ $\Delta E = 0.444\ \text{W} \times 7 \times 24 \times (60 \times 60)\text{s} = 2.69 \times 10^5\ \text{J}$	6

Q2.

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

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

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

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

Q3.

Question Number	Acceptable Answer		Additional Guidance	
	• Use of $s = \frac{(u+v)}{2}.t$ • Use of $E_k = \frac{1}{2}mv^2$ • Use of $P = \frac{\Delta W}{\Delta t}$ • $P = 110$ W	(1) (1) (1) (1)	Example of calculation: $32.5\text{ m} = \frac{(u+0)}{2} \times 17.5\text{ s}$ $\therefore u = \frac{32.5\text{ m} \times 2}{17.5\text{ s}} = 3.71\text{ m s}^{-1}$ $P = \frac{\Delta E_k}{\Delta t} = \frac{\frac{1}{2} \times 19.6\text{ kg} \times (3.7\text{ m s}^{-2})^2}{1.25\text{ s}} = 107\text{ W}$	4

Q4.

Question Number	Acceptable answers		Additional guidance	Mark
(i)	• Use of $\Delta W = F\Delta s$ and $P = W/t$ • Use of $F = ma$ • $a = 0.31\text{ m s}^{-2}$	(1) (1) (1)	Example of calculation: In 1 second $W = F\Delta s$ $4500\text{ W} = F \times 34\text{ m s}^{-1}$ Force applied by motor = 132 N $F = ma$ $132\text{ N} = 420\text{ kg} \times a$ $a = 0.31\text{ m s}^{-2}$	3
(ii)	• Neglect friction forces when it starts from rest **Or** Motor/Driving force independent of speed	(1)	Do not accept "force" without a description	1

Q5.

Question Number	Acceptable Answer		Additional guidance	Mark
(a)	• use of $T = \frac{2\pi}{w}$	(1)	Example of calculation: $w = \frac{2\pi}{(60 \times 60)\ s}$	**(2)**
	• 1.7×10^{-3} rad s^{-1} or $\frac{\pi}{1800}$ rad s^{-1}	(1)		

Question Number	Acceptable Answer		Additional guidance	Mark
(b)	• recognises weight acts halfway along hand	(1)	Example of calculation: $W = 0.014\ \text{kg} \times 9.81\ \text{N kg}^{-1} \times (2 \times 0.04 \sin 6^\circ\ \text{m})$	**(5)**
	• uses correct angle between the two positions	(1)	$W = 1.1 \times 10^{-3}\ \text{J}$	
	• determines change in vertical height (= 0.008 m)	(1)		
	• use of $\Delta E = mg\Delta h$	(1)		
	• work done = 1.1 (mJ)	(1)		

Question Number	Acceptable Answer		Additional guidance	Mark
(c)	• use of $P = VI$	(1)	Example of calculation: $P = 1.5\ \text{V} \times 8.0 \times 10^{-6}\ \text{A} = 1.2 \times 10^{-5}\ \text{W}$ $t = \frac{1.1 \times 10^{-3}\ \text{J}}{0.65 \times 1.2 \times 10^{-5}\ \text{W}} = 141\ \text{s}$	**(3)**
	• use of $P = \frac{W}{t}$ AND 65%	(1)		
	• t = 141 s	(1)		

Q6.

Question Number	Answer	Mark
(a)(i)	Use of $P = IV$ (1) Power = 2900 W (1) Example of calculation Power = 12.5 A × 230 V = 2875 W	2
(a)(ii)	$P = E/t$ (1) Energy = 400 000 J (ecf from (i)) (1) Example of calculation Energy = 2875 W × 140 s = 402 500 J	2
(a)(iii)	Use of efficiency = useful energy output / total energy input (1) = 0.87 or 87% (ecf from (ii)) (do not award if > 100%) (1) Example of calculation Efficiency = 351 000 J / 402 500 J = 0.87 or 87%	2
(b)	Some energy transferred by heating the kettle / element / wires / surroundings **Or** Some energy transferred as sound (1) So not all of the (input) energy is transferred to (heating) the water **Or** so useful energy output is less than energy input **Or** only the energy heating the water is useful (1)	2
	Total for question	8

Q7.

Question Number	Acceptable answers	Additional guidance	Mark
	• Use of $\Delta E_{grav} = mg\Delta h$ (1) • convert for a unit time, e.g. day or second ie W (1) • Calculation of energy input provided by coal in unit time (1) • Use of Efficiency = energy output/energy input (1) **Or** in terms of power • Efficiency = 1.5 % so not correct (1)	(allow reverse argument starting with 10% efficiency for full credit) Example of calculation: $\Delta E_{grav} = 2500 \times 9.81 \times 12$ $\Delta E_{grav} = 294\text{kJ per minute}$ $\Delta E_{grav} = 294\text{kJ} \times 60 \times 24$ $\Delta E_{grav} = 424\text{MJ per day}$ energy input = 1250 × 22.3 MJ Efficiency = 424 MJ/ 27900 MJ = 1.5%	5

Q8.

Question Number	Acceptable Answer		Additional Guidance	Mark
(a)(i)	• Use of $P = VI$ • $P = 1900$ W (1.9 kW)	(1) (1)	Example of calculation $P = 230\ \text{V} \times 8.20\ \text{A} = 1890\ \text{W}$	2
(a)(ii)	• Use of $\Delta E = mc\Delta\vartheta$ • Use of $P = \frac{\Delta E}{\Delta t}$ • $\Delta t = 112$ s or 113 s [106 s or 107 s if show that value used] ECF from (a)(i)	(1) (1) (1)	Example of calculation $\Delta E = 0.655\ \text{kg} \times 4190\ \text{J kg}^{-1}\text{K}^{-1} \times (100 - 22.5)\text{K}$ $\Delta E = 2.13 \times 10^5\ \text{J}$ $\Delta t = \frac{2.13 \times 10^5\ \text{J}}{1890\ \text{W}} = 112.5\ \text{s}$	3

Question Number	Acceptable Answer		Additional Guidance	Mark
(b)(i)	• After a short time of boiling in the flask, all the apparatus would be at 100 °C. **Or** so energy is not being used to heat up the flask **Or** so steam won't condense in the flask	(1)		1
(b)(ii)	• Use of $\Delta E = mL$ • Use of $P = \frac{\Delta E}{\Delta t}$ • 1720 W (1.72 kW)	(1) (1) (1)	Example of calculation $\frac{\Delta m}{\Delta t} = \frac{95 \times 10^{-3}\ \text{kg}}{125\ \text{s}}$ $= 7.6 \times 10^{-4}\ \text{kg s}^{-1}$ $\frac{\Delta E}{\Delta t} = 7.6 \times 10^{-4}\ \text{kg s}^{-1} \times 2.26 \times 10^6\ \text{J kg}^{-1}$ $P = 1720\ \text{J s}^{-1}$	3
(b)(iii)	• Comparison of answer to (a)(i) with answer to (b)(ii) • Not all of the energy from the heater is used to turn water from liquid state into vapour **Or** energy is being used to heat the heat exchanger **Or** not all the steam condenses in the heat exchanger • Some energy is transferred to the surroundings	(1) (1) (1)	e.g. rate at which thermal energy is supplied to the water in the flask is greater than rate at which thermal energy is removed from the water in the heat exchanger. If answer for (b)(ii) is bigger than 2 kW,1 mark for correct comparison can be scored.	3

Q9.

Question Number	Acceptable Answer	Additional guidance	Mark
	C	$\frac{mgh}{t}$	**(1)**

Q10.

Question Number	Acceptable answers	Additional guidance	Mark
(a)	• use of $W = VIt$ (1) • use of $\Delta E = mc\Delta\theta$ (1) • use of efficiency = useful power output / total power input (1) • efficiency = 0.90 Or 90% (1)	Example of calculation: W = 247 V × 11.8 A × 172 s = 501 000 J ΔE = 1.20 kg × 4180 J kg^{-1} K^{-1} × (101 - 11) K = 451 000 J Efficiency = 451 000 / 501 000 = 0.90	**(4)**

Question Number	Acceptable answers	Additional guidance	Mark
(b)	• calculates area of sphere of radius 30 cm = 1.13 m^2 (1) • use of $I = P/A$ (1) • use of $W = Pt$ (1) • W = 2.0 J (1)	Example of calculation: Area = 4π × (0.3 m)^2 = 1.13 m^2 P = 10.5 × 10^{-3} W m^{-2} × 1.13 m^2 = 1.19 × 10^{-2} W W = 1.19 × 10^{-2} W × 172 s = 2.0 J	**(4)**

Question Number	Acceptable answers	Additional guidance	Mark
(c)	An explanation that makes reference to the following: • the quiet boil electric kettle is more efficient, but only by 3% which isn't 'much' (1) • the energy transferred by sound is very small, so it is not the reason for the difference (1)	Allow 1 mark if the student gives a comment that the uncertainties are too high to draw a valid conclusion without reference to the data in the question, the candidate's calculations may be awarded one mark	**(2)**

Mark Scheme

Q1.

Question Number	Acceptable answers	Additional guidance	Mark
	• Use of $\Delta E = mc\Delta\theta$ **(1)** • Use of $\Delta E = L\Delta m$ **(1)** • Apply 5% to calculate energy saved **(1)** • Use of $P = VI$ **or** Use of $Q = It$ **(1)** • Use of $P = \frac{W}{t}$ **or** Use of $E = QV$ **(1)** • 2.69×10^5 J compared with 1.93×10^5 J for energy saved, and concludes claim invalid. **(1)** **Or** a phone could run for 5 days compared to 7 days and conclusion claim invalid **Or** a phone could run for 433 900 s compared to 604 800 s and conclusion claim invalid	Example of calculation: For aluminium when being heated up to m.pt.: $\Delta E = 14 \times 10^{-3}\ \text{kg} \times 902\ \text{J kg}^{-1}\text{K}^{-1} \times (660 - 293)\text{K}$ $\Delta E = 4.63 \times 10^3\ \text{J}$ For aluminium when melting: $\Delta E = 14 \times 10^{-3}\ \text{kg} \times 396 \times 10^3\ \text{J kg}^{-1} = 5.54 \times 10^3\ \text{J}$ Energy saved $= \frac{0.95}{0.05} \times (4630 + 5540)\text{J}$ Energy saved $= 1.93 \times 10^5\ \text{J}$ $P = 3.7\ \text{V} \times 120 \times 10^{-3}\ \text{A} = 0.444\ \text{W}$ $\Delta E = 0.444\ \text{W} \times 7 \times 24 \times (60 \times 60)\text{s} = 2.69 \times 10^5\ \text{J}$	**6**

Q2.

Question Number	Acceptable Answer		Additional Guidance	Mark
	• Use of $E_K = \frac{1}{2}mv^2$	**(1)**	Example of calculation $E_K = \frac{1}{2} \times 1.75\ \text{kg} \times (6.25\ \text{m s}^{-1})^2 = 34.2\ \text{J}$ $\Delta E = 0.65 \times 8000 \times 34.2\ \text{J} = 1.78 \times 10^5\ \text{J}$ $\Delta E = 0.875\ \text{kg} \times 1770\ \text{J kg}^{-1}\text{K}^{-1} \times (165 - 23)\text{K}$ $\therefore \Delta E = 2.20 \times 10^5\ \text{J}$ $E_K = \frac{1}{2} \times 1.75\ \text{kg} \times (6.25\ \text{m s}^{-1})^2 = 34.2\ \text{J}$ $\Delta E = 0.65 \times 34.2\ \text{J} = 22.2\ \text{J}$ $\Delta E = 0.875\ \text{kg} \times 1770\ \text{J kg}^{-1}\text{K}^{-1} \times (165 - 23)\text{K}$ $\therefore \Delta E = 2.20 \times 10^5\ \text{J}$ $\text{Number of slaps} = \frac{2.20 \times 10^5\ \text{J}}{22.2\ \text{J}} = 9910$ $E_K = \frac{1}{2} \times 1.75\ \text{kg} \times (6.25\ \text{m s}^{-1})^2 = 34.2\ \text{J}$ $\Delta E = 0.65 \times 8000 \times 34.2\ \text{J} = 1.78 \times 10^5\ \text{J}$ $1.78 \times 10^5\text{J} = 0.875\ \text{kg} \times 1770\ \text{J kg}^{-1}\text{K}^{-1} \times (T_f - 296)\text{K}$ $\therefore T_f = \frac{1.78 \times 10^5\ \text{J}}{1.55 \times 10^3\ \text{J K}^{-1}} + 296\ \text{K} = 411\ \text{K}$ $\therefore \theta_f = (411 - 273)\ \text{K} = 138\ ^\circ\text{C}$ MP5: must see a correct value as part of the conclusion	**5**
	• Use of $\Delta E = mc\Delta\theta$	**(1)**		
	• Use of 8000 **Or** use of (energy required) / (energy per slap)	**(1)**		
	• Use of 65% with input energy • Energy from 8000 slaps would be 1.78×10^5 J which is less than the energy required to raise the temperature to 165 °C (2.20×10^5 J) **Or** final temperature would be 138 °C, so not enough **Or** 9900 slaps would be needed, so not enough **Or** temperature rise from 8000 slaps is 115 K which is less than required temperature rise of 142 K	**(1)**		

Q3.

Question Number	Answer		Mark
(a)(i)	Use of $P = IV$ Power = 2900 W <u>Example of calculation</u> Power = 12.5 A × 230 V = 2875 W	(1) (1)	2
(a)(ii)	$P = E/t$ Energy = 400 000 J (ecf from (i)) <u>Example of calculation</u> Energy = 2875 W × 140 s = 402 500 J	(1) (1)	2
(a)(iii)	Use of efficiency = useful energy output / total energy input = 0.87 or 87% (ecf from (ii)) (do not award if > 100%) <u>Example of calculation</u> Efficiency = 351 000 J / 402 500 J = 0.87 or 87%	(1) (1)	2
(b)	Some energy transferred by heating the kettle / element / wires / surroundings **Or** Some energy transferred as sound So not all of the (input) energy is transferred to (heating) the water **Or** so useful energy output is less than energy input **Or** only the energy heating the water is useful	(1) (1)	2
	Total for question		8

Q4.

Question Number	Acceptable answers		Additional guidance	Mark
	• Use of $\Delta E_{grav} = mg\Delta h$ • convert for a unit time, e.g. day or second ie W • Calculation of energy input provided by coal in unit time • Use of Efficiency = energy output/energy input **Or** in terms of power • Efficiency = 1.5 % so not correct	(1) (1) (1) (1) (1)	(allow reverse argument starting with 10% efficiency for full credit) Example of calculation: $\Delta E_{grav} = 2500 \times 9.81 \times 12$ $\Delta E_{grav} = 294\text{kJ per minute}$ $\Delta E_{grav} = 294\text{kJ} \times 60 \times 24$ $\Delta E_{grav} = 424\text{MJ per day}$ energy input = 1250 × 22.3 MJ Efficiency = 424 MJ/ 27900 MJ = 1.5%	5

Q5.

Question Number	Acceptable answers		Additional guidance	Mark
(a)	• use of $W = VIt$ • use of $\Delta E = mc\Delta\theta$ • use of efficiency = useful power output / total power input • efficiency = 0.90 Or 90%	(1) (1) (1) (1)	Example of calculation: W = 247 V × 11.8 A × 172 s = 501 000 J ΔE = 1.20 kg × 4180 J kg^{-1} K^{-1} × (101 - 11) K = 451 000 J Efficiency = 451 000 / 501 000 = 0.90	**(4)**

Question Number	Acceptable answers		Additional guidance	Mark
(b)	• calculates area of sphere of radius 30 cm = 1.13 m^2 • use of $I = P/A$ • use of $W = Pt$ • W = 2.0 J	(1) (1) (1) (1)	Example of calculation: Area = 4π × (0.3 m)^2 = 1.13 m^2 P = 10.5 × 10^{-3} W m^{-2} × 1.13 m^2 = 1.19 × 10^{-2} W W = 1.19 × 10^{-2} W × 172 s = 2.0 J	**(4)**

Question Number	Acceptable answers		Additional guidance	Mark
(c)	An explanation that makes reference to the following: • the quiet boil electric kettle is more efficient, but only by 3% which isn't 'much' • the energy transferred by sound is very small, so it is not the reason for the difference	(1) (1)	Allow 1 mark if the student gives a comment that the uncertainties are too high to draw a valid conclusion without reference to the data in the question, the candidate's calculations may be awarded one mark	**(2)**

Q6.

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	An explanation that makes reference to the following points: • Radiation is absorbed/scattered passing through the atmosphere. (1) • Radiation is reflected from the top of the atmosphere (1) • Only half of the Earth's surface has radiation from the Sun incident on it at any one instant. (1) • The intensity of radiation (normal to the surface) is greater at the equator than at the poles. (1)		4

(ii)	• Use of $A=4\pi r^2$ (1) • Use of efficiency= $\frac{\text{useful power output}}{\text{total power input}}$ (1) • Use of $I=\frac{P}{A}$ (1) • % of surface needed is 0.0005%, so claim is not valid (1) [Accept reverse calculation to show power generated by cells over 0.5% of the Earth would generate 1.06×10^5 GW]	<u>Example of calculation:</u> $A=\frac{P}{I}$ $=\frac{100\times10^9\ \text{W}}{0.25\times164\ \text{W m}^{-2}}=2.44\times10^9\text{m}^2$ $A=4\pi\times(6.4\times10^6\ \text{m})^2$ $=5.15\times10^{14}\text{m}^2$ % needed = $\frac{2.44\times10^9\text{m}^2}{5.15\times10^{14}\ \text{m}^2}\times100\%=0.00047\ \%$	4