Question			Answer	Marks	Guidance
1			Any <u>one</u> from: • Mass obtained using a balance / scales • Weight / load obtained using a newtonmeter / spring balance • Distance / height obtained using a ruler / metre stick / measuring tape	B1	
			Time obtained using a clock / (stop)watch / timer or light-gate <u>and</u> timer or light-gate <u>and</u> data-logger	B1	✎ The term **clock** / **(stop)watch / timer /data-logger** must be spelled correctly to gain this mark
			(output power =) 'mass × *g* × distance'/time or 'weight × distance/time' or 'weight × speed'	B1	**Allow** symbols, e.g *mgh/t*, *Wh/t* and *Wv*
			input power = output power/0.15	B1	
			Total	**4**	

Question			Expected Answers	Marks	Additional Guidance
2	a		**Measurements**: height (of wall) time (of fall) **Instruments**: ruler / tape (measure) stopwatch / timer / clock /video $g = \frac{2s}{t^2}$ / g = 2 × gradient of s-t^2 graph **Note**: Allow full credit if candidate has used alternative approaches using $v^2 = u^2 + 2as$ or $v = u + at$. Any <u>two</u> from: g is an estimate because • air resistance / drag ignored • parallax problems with 'landing time' • starting / stopping the clock	 B1 B1 B1 B1 B1 B1×2	**Must use tick or cross on Scoris to show if the mark is awarded** **Allow:** 'distance (of fall)' instead of 'height' ✎ **The 4th B1 can only be scored if *stopwatch* / *timer* / *clock* / *video* (camera) is spelled correctly** **Allow:** Use of 'a' instead of 'g' **Note**: a must be the subject **Allow:** 'wind resistance'/'resistive force' for first bullet point **Allow**: 'reaction time' but **not** 'human error' for the third bullet point
	b	i	Radio (waves) / microwaves	B1	
		ii	Time taken for the signal to travel from satellite to car is determined / 'delay' time for signal is determined distance = c × (delay) time	M1 A1	 **Allow**: speed of light / 3.0×10^8 <u>m s^{-1}</u> instead of c **Note:** Distance must be the subject for the second B1 mark

Question			Expected Answers	Marks	Additional Guidance
		iii	Mention of circles / spheres / shells	B1	**Note**: This mark can be scored if a diagram shows circles / arcs (no label required)
			The position of the car is where the circles intersect / trilateration mentioned	B1	**Note**: This mark can be scored on a diagram if it shows intersecting circles / arcs and the intersection point is marked 'car'
			Total	**12**	

Question			Answer	Marks	Guidance
3			**Diagram showing** • Oil in (insulated) container • Electrical heater <u>fully immersed in oil</u> • <u>Thermometer / Temperature sensor</u> **Electrical circuit** • Ammeter in series , voltmeter in parallel with heater / joulemeter in parallel with heater • Power supply /+ & - signs marked on wires **Measurements** • Measure mass of oil /use known mass of oil, • Measure change in temperature / initial and final temperatures • Measure current, pd and (fixed) time / energy **Calculation** $\text{Input Energy} = E = Pt = VIt$ and $c = \frac{E}{m\Delta\vartheta}$ **Uncertainties** Any **two** together with minimising action. • Heat losses (make $\Delta\vartheta$ uncertain) - minimise by using initial ϑ below and final ϑ <u>same amount</u> above, room temperature • Temperature varies throughout oil - minimise by stirring before taking temperature readings • Some energy is required to raise temperature of the container / heater (etc) - allow by including in calculation. • Temperature will continue to rise after heater is turned off – find max temperature.	B1 B1 B1 B1 2 x B1	**Not:** oven or hotplate **Allow:** 'Fully immersed' seen in the body of text **Thermometer /Temperature sensor** must be spelled correctly on diagram All elements should be shown to score these diagram marks. Ignore appropriate additional items Connections to heater should be clear. Must have all elements. **Allow:** Use of symbols **Allow:** Take energy reading from joulemeter **Not:** use given power rating of heater Input energy must be consistent with equipment used. c must be the subject of the equation and temperature **rise** ($\Delta\vartheta$ or $\vartheta_2 - \vartheta_1$) must be clear. **Allow**: Draw graph of temperature against time $c = VI$ / [gradient x mass] These points may be scored in the description of method. No credit for other uncertainties including heat lost to surroundings
			Total	6	

Q4	Expected Answers	Marks	Additional guidance
(a)(i)	Force/acceleration is proportional to displacement **(**from equilibrium position**)** (Resultant force) force/acceleration is (always) towards equilibrium position (WTTE, e.g. allow fixed point).	B1 B1	**Allow** force/acceleration is in opposite direction to the displacement. **Allow** acc $\propto x$, provided x is identified as the displacement for 1st mark. 2nd mark only scored if –ve sign used and explained.
(a)(ii)	True; False False; False	B2	-1 for each error stop at zero Assume ✓ means true and X means false Do not credit blank spaces
(b)	***Measurements***: angle measured <u>with protractor</u> stated or shown on the diagram <u>stop-watch/ms timer/data-logger</u> to measure time stated or shown on the diagram ***Conclusion:*** compare periods for different angles stated/implied OR plot period against angle ***major difficulty:*** angle of swing decreases during the timing of the swing ***solution:*** e.g. measure time for ¼, ½ or 1 swing accurately (using electronic timer/datalogger) OR use data logger with motion sensor to record many swings and analyse how the period changes over time OR video the motion with onscreen timer and analyse	 B1 B1 B1 M1 A1	**Allow** ruler used to measure initial and subsequent displacement/amplitude if explained. **Allow** table of results with correct column headings i.e. at least angle and period Do not allow ‘time is short so measure nT and divide by n to reduce (%) error’.(WTTE)
	Total	**9**	

Question			Expected Answers	Marks	Additional guidance
5	(a)		Any <u>four</u> from 1 to 5: 1. Most of the alpha particles went straight through (some deviated through small angles) 2. Hence most of the atom is empty space 3. Some / a very small number of alpha particles were scattered / repelled through large angles / angles more than 90° 4. This showed the existence of (a tiny) positive nucleus 5. The size of the nucleus is about 10^{-14} <u>m</u> ✍ QWC: Award a mark for one conclusion correctly linked to an observation	B1×4 B1	**Must use ticks on Scoris to show where the marks are awarded** **Allow**: 10^{-15} <u>m</u>
	(b)		Any <u>five</u> from: Gravitational (force) This force is attractive **AND** is long-ranged / obeys '1/r^2 relationship' <u>Strong</u> (nuclear force/interaction) This force is attractive (at larger distances) or repulsive at short distances **AND** is short-ranged / ~ 10^{-14} m Electrostatic / electrical (force) / coulomb (force) This force is repulsive between protons / zero between neutrons / zero between protons and neutrons **AND** is long-ranged / obeys '1/r^2 relationship'	M1 A1 M1 A1 M1 A1	**Allow:** gravity **Note**: Do not allow 'inverse square law'; allow 'inverse square law with distance' **Allow:** Electromagnetic (interaction/force)

Question			Expected Answers	Marks	Additional guidance
	(c)	**(i)**	mass = $235 \times 1.7 \times 10^{-27}$ ($= 3.995 \times 10^{-25}$ kg)	C1	**Allow:** 1.66×10^{-27} kg for mass of nucleon
			volume = $\frac{4}{3}\pi \times (8.8 \times 10^{-15})^3$ ($= 2.855 \times 10^{-42}$ m^3)	C1	
			density = mass/volume		
			density = 1.4×10^{17} (kg m^{-3})	A1	**Allow:** 10^{17} (kg m^{-3}) for this estimation question **Note:** Omitting 235 gives 6.0×10^{14} (kg m^{-3}), allow 2 mark **Allow:** 1 mark if 92 or 143 is used to determine the mass of the nucleus; this gives a density value of 5.5×10^{16} (kg m^{-3}) and 8.5×10^{16} (kg m^{-3}) respectively
		(ii)	The nucleons / neutrons and protons are packed together with little or no empty space (AW)	B1	
			Total	14	

Question			Answer	Marks	Guidance
4	(a)		Obtain a set of readings for: mass *m*, time period AND calculate frequency using $f = 1/T$. Plot graphs of *f* against 1/*m* AND *f* against $1/\sqrt{m}$ The graph which is a straight line through the origin provides the correct relationship Reference to one method of improving reliability eg counting more than 5 oscillations to find *T* or *f* taking repeat measurements of *T* or *f* (and average values) time oscillations from equilibrium position	B1 B1 B1 B1	**Not** number of oscillations in a set time **Allow:** product method using two or more points (B1) Select the relation which gives a constant product (B1) **Allow:** plot ln *f* against ln *m* (B1) gradient= -1 then $f \propto 1/m$ **or** gradient= -0.5 then $f \propto 1/\sqrt{m}$ (B1)
	(b)	(i)	$v_{max} = 2\pi f A = 2\pi\left(\frac{1}{1.2}\right)\times 36\times 10^{-3}$ $v_{max} = \frac{3\pi}{50} \quad (= 0.188)$ $KE_{max} = \frac{1}{2}\times 0.4\times\left(\frac{3\pi}{50}\right)^2$ $KE_{max} = 7.1\times 10^{-3}$ (J)	C1 C1 A1	**Note:** mark is for substitution
		(ii)	$a_{max} = (2\pi f)^2 A = \left[2\pi\left(\frac{1}{1.2}\right)\right]^2 \times 36\times 10^{-3}$ $a_{max} = 0.99$ (ms^{-2})	C1 A1	**Note:** mark is for correct substitution

Question			Answer	Marks	Guidance
	(c)		**Reference to** : kinetic energy (of masses and spring), gravitational potential energy (of mass and spring), elastic (potential) energy / strain energy of spring KE: zero (at lowest point), increasing to max at equilibrium point, decreasing to zero (at highest point) GPE: increases (as masses rise from lowest to highest point) (clearly worded ora)(AW) strain / elastic energy: decreases (as masses rise from lowest to highest point) (clearly worded ora) (AW)	B1 B1 B1 B1	**Note:** mark to be awarded only if **all** 3 forms are quoted ✎ **Note: potential** must be spelled correctly throughout to score this mark
			Total	**13**	