1)

Question			Answer	Marks	Guidance
1	(a)		Rate of change of momentum (of a body) is proportional / equal to the (net) force (acting on it) and takes place in the direction of that force.	M1 A1	**Allow:** Force = change in momentum / time (taken) **Note: momentum** must be spelled correctly to score the mark. **Allow** this mark if the M1 mark is lost for spelling error
	(b)	**(i)**	(3 x 5) – (7 x 2) = 10v v = (15 – 14)/10 = 0.10 (m s^{-1}) to the right (AW)	C1 M1 A1	Signs must be correct for the mark to be scored **Allow** 1 sf answer **Not** forwards/towards **B** but **allow** correct arrow → or east
		(ii)	Impulse = 3(0.1 – 5) (= - 14.7) = (-)15 (Ns) to the left (AW)	 M1 A1	**Allow:** ecf from (b)(i) **Ignore** sign **Not** backwards/towards **A** but **allow** correct arrow ← or west
		(iii)	(Newton's 3rd law says) Force on B (due to A) is equal and opposite to force on A (due to B) time (of contact) / t is same for both **AND** Impulse = Ft impulse on A is equal and opposite to impulse on B	 M1 A1 A0	**Allow**: use of minus sign to indicate 'opposite' **Not**: Action and reaction are equal and opposite.
			Total	**9**	

2)

Question			Answer	Mark	Guidance
	(a)	(i)	*N* & *W* act on the same body / Newton's 3rd Law forces should act on different bodies *N* & *W* are different types (of force) / are not same type	B1 B1	**Allow:** 3rd law pair to W acts on (centre of)Moon 3rd law pair to N acts on surface of Moon **Allow:** *N* is electromagnetic/electrostatic/electrical/contact *W* is gravitational. **Allow:** Paired forces should be of the same type **Ignore** a general statement of Newton's 2nd or 3rd law
		(ii)	Equal to / same as *W* acting on (the centre of) the Moon	B1	Do not allow 'acts on **surface** of Moon Diagram is not sufficient for this mark
	(b)		Clear use of vertical motion with downward acceleration **and** horizontal motion at constant velocity vertically $0 = (u\sin\theta)t - \frac{1}{2}g_M t^2$ $t = \frac{2u\sin\theta}{g_M}$ horizontally $x = u\cos\theta \times \frac{(2u\sin\theta)}{g_M}$ $x \propto \frac{u^2}{g_M}$	B1 M1 A1 A0	If sin θ and cos θ are confused allow max 1/3. **Allow:** use of a for g_m **Allow:** determination of time to max height using $v=u+at$ Then total time = 2 x time to max height (M1) **Allow** use of 9.81 instead of g_m
			Total	**6**	

3)

Question			Answer	Mark	Guidance
	(a)	(i)	$m = \frac{0.131}{6.02\times10^{23}}$ $m = 2.18\times10^{-25}$ (kg)	A1	
		(ii)	mass of xenonejected/ s = $m_{Xe} = 2.2\times10^{-25}\times9.5\times10^{18}$ $(=2.07\times10^{-6})$ $F_{Xe} = \left(m_{Xe}\frac{\Delta v}{\Delta t}\right) = 2.2\times10^{-25}\times9.5\times10^{18}\times3.2\times10^{4}$ $(=0.06627)$ $a_S = \left(\frac{F_{Xe}}{m_s}\right) = \frac{2.2\times10^{-25}\times9.5\times10^{18}\times3.2\times10^{4}}{5.2\times10^{3}}$ $a_S = 1.3\times10^{-5}$ (m s^{-2})	C1 C1 A1	Possible ECF **Allow:** $5.2\times10^{3}\times\Delta v = 2.07\times10^{-6}\times3.2\times10^{4}$ $\Delta v = 1.3\times10^{-5}$ $a_S = 1.3\times10^{-5}$ (m s^{-2})
		(iii)	Rate of change of **momentum** (of an object) is proportional to the resultant / net (external) force acting upon it. (AW) **OR** statement of law of Conservation **of momentum** in a closed system/no external forces	B1	**Momentum** must be spelled correctly **Allow:** ' equal to' instead of 'proportional to' **Allow:** statement of Newton's 3rd Law provided it is clear the forces act on **different** bodies and **opposite** is spelled correctly
		(iv)	Force (on spacecraft) is constant Mass (of spacecraft) decreases (as xenon is ejected) Acceleration increases	B1 M1 A1	**Not:** Weight (of spacecraft) or 'it is lighter'
	(b)	(i)	Area under graph in range 10.5 to 11.5 (Ns) Area under graph in range 10.8 to 11.2 (Ns) $\Delta v = \frac{\text{impulse}}{m} = \frac{\text{area}}{m}$ $= \frac{11.0}{180}$ $= 6.1\times10^{-2}$ (ms^{-1})	C1 C1 C1 A1	Possible FT for using their area / 180 Use of mass of spacecraft rather than satellite scores 1 out of last 2 marks.
		(ii)	From 0 to 3 (ms) acceleration increases linearly/uniformly/ at constant rate/ at a steady rate. (From 6.5 ms) onwards/later/at end the acceleration decreases	B1 B1	**Allow:** upper limit on time in range 3.0 to 3.5 ms Do not credit use **of 'constantly'** for this mark **Not 'decelerates'**
			Total	**14**	

4)

Question			Answer		Mark	Guidance
	(a)	(i)	Gradient /It is the **acceleration** which is the same (for both) (AW)		B1	**Note:** **acceleration** must be spelled correctly for this mark **Allow**: Gradient /It is the **acceleration** and **acceleration** is free fall/*g*/9.8 (1)
		(ii)	Collision is inelastic / kinetic energy is lost (on impact with the ground) Idea that area is height (above ground) / Height (at E) is less (than height of A) (AW)		B1 B1	**Not** heights are not the same **Allow:** displacement or distance travelled by ball for height
	(b)	(i)	$u^2 = 2\times9.8(1)\times1.7$ $(=33.32)$ $u = 5.8$ (m s^{-1})		B1	**Not** $g = 10$ **Note** answer to 3 sf is 5.78 (m s^{-1})
		(ii)	**EITHER** $F\Delta t = m(v-u)$ **and** $F\Delta t = 16\times75\times10^{-3}$ $16\times75\times10^{-3} = 0.13\times[v-(-5.78)]$ $v = 3.5$ (ms^{-1})	**OR** $a = F/m$ = 16/0.13 (a =123) (upwards positive) v = -5.78 +123 x 75 x 10^{-3} = 3.5 (m s^{-1})	C1 A1	**Allow** ECF from b(i) **Allow** v = $\frac{14}{23}$ x 5.78 (from graph for C1 mark) **Note:** answer to 3 sf is 3.46 (ms^{-1}) Using u = - 5.8 leads to v = 3.4 scores 2/2 Using u = +5.78 leads to v = 15 scores 1/2 Using equation of motion with a = 9.8(1) is WP scores 0/2
		(iii)	$h = \frac{v^2}{2g} = \frac{3.46^2}{2\times9.8}$ $h = 0.61$ (m)		B1	**NO ECF** **Allow** graphical method using $h \propto v^2$ **Allow** answer in range 0.59 – 0.63 (m)
				Total	**7**	

5)

Question			Answer	Mark	Guidance
	(a)		A body will remain at rest or keep travelling at constant velocity unless acted upon by a resultant/net (external) force (AW)	B1	**Allow** 'speed in straight line' for velocity **Allow** 'uniform motion'
	(b)	(i)	They have equal magnitude/ same size They are the same type / nature	B1 B1	**Allow** act for the same time **Allow** have same line of action
		(ii)	Act in opposite directions Act on different bodies	B1 B1	**Not** act in different directions
	(c)	(i)	$\frac{dm}{dt} = \rho A v$ $= 1\times10^{3}\times3.3\times10^{-4}\times25$ $(= 8.25\ \text{kg s}^{-1})$	B1	
		(ii)	Weight (of fireman) = $92g$ / W = 92 x 9.8(1) (= 903 N) Vertical component of water force = 8.25 x 25 sin 55 (= 169 N) Vertical component of contact force = 169 + 903 = 1100 N	C1 M1 A1	**Allow** use of 8.3 leading to 170 N **Note** answer to 3 sf is 1070 N **Note:** a **bald** $\frac{92g}{\sin 55} = 1100$ is WP scores 0/3
			Total	**9**	

6)

Question			Answer	Marks	Guidance
	a		Energy of ∝ = $5.2\times10^{6}\times1.6\times10^{-19}$ (= 8.32×10^{-13} (J)) $E = ½ mv^2$ so $v = \sqrt{\frac{2\times8.32\times10^{-13}}{6.6\times10^{-27}}}$ $= 1.6\times10^{7}$ (m s^{-1})	C1 A1 A0	Must see some working **Allow:** Max 1 mark for 4 x 10^{16} (not converting to J) or 1.6 x 10^{4} (not converting MeV to eV) 5.1 x 10^{5} (using keV rather than MeV)
	b		Any **three** from • Total **momentum** of system / particles is conserved (as there are no external forces) / Increase in momentum of Sr nucleus equals decrease in momentum of alpha-particle • (Electrostatic) force (of repulsion) acts on (Sr) nucleus • (By Newton's 2nd law Sr) nucleus accelerates (away from alpha particle) • Sr acceleration increases and then decreases (to zero) • Force on Sr nucleus ∝ rate of change of momentum of alpha particle. (AW)	B1 × 3	**momentum / accelerate(s) / acceleration** must be spelled correctly to score corresponding mark
	c		(Momentum is conserved) $6.6\times10^{-27}\times1.6\times10^{7} = 1.3\times10^{-25}\times V$ $V = 8.1\times10^{5}$ (ms^{-1})	C1 A1	**Possible ECF from (a)** **Allow** full marks for use of 2 x 10^{7} for speed of alpha particle giving V = 1.0 x 10^{6} (m s^{-1})
	d		$\Delta(mv)$ = 2 × 6.6 × 10^{-27} × 1.6 × 10^{7} (= 2.11 × 10^{-19}) $F\Delta t = 4.8\times\Delta t = 2.11\times10^{-19}$ $\Delta t = 4.4\times10^{-20}$ (s)	C1 A1	**Possible ECF from (a)** **Allow** full marks for use of 2 x 10^{7} for speed of alpha particle giving Δt = 5.5 x 10^{-20} (s)
			Total	**9**	