Question Number	Answer	Mark
***1(a)(i)**	**(QWC – work must be clear and organised in a logical manner using technical terminology where appropriate)** Measure the mass of each glider **(1)** Measure the length of the card **(1)** Recognise the time (for the card) to pass the light gate **(1)** Calculate the velocity using length (of card)/time **(1)** Recognise the need to show that $m_1v_1 = (m_1+m_2)v$ **Or** the equivalent description in words **(1)**	**5**
1(a)(ii)	Law of conservation of momentum only applies when no external forces act **(1)** Friction would be an external force **Or** Friction would alter/affect the velocities (immediately before and after the collision) **Or** there is time between the readings during which friction acts **(1)**	**2**
1(b)(i)	Use of $p=mv$ to determine momentum before **and** after collision **(1)** $v = 0.50$ m s^{-1} **(1)** Example of calculation $v = \frac{(0.50\text{ kg} \times 0.90\text{ m s}^{-1}) - (0.50\text{ kg} \times 0.20\text{ m s}^{-1})}{0.70\text{ kg}} = 0.50\text{ m s}^{-1}$	**2**
1(b)(ii)	E_k before collision = 0.20 J **(1)** E_k after collision = 0.10 J hence inelastic collision (ecf from (b)(i)) **(1)** (correct calculation of energy difference = 0.1 J and conclusion scores both marks) Example of calculation Before $E_k = \frac{1}{2} \times 0.50\text{ kg} \times (0.90\text{ m s}^{-1})^2 = 0.20$ (J) After $E_k = \left(\frac{1}{2} \times 0.50\text{ kg} \times (0.20\text{ m s}^{-1})^2\right) + \left(\frac{1}{2} \times 0.70\text{ kg} \times (0.50\text{ m s}^{-1})^2\right) = 0.098$ (J)	**2**
	Total for question	**11**

Question Number	Answer	Mark
***2**	(QWC – Work must be clear and organised in a logical manner using technical wording where appropriate) statement that indicates that the conservation of momentum does apply **(1)** the idea that the probe and tank move in opposite directions [accept move apart] **Or** the idea that the probe and tank experience equal and opposite forces **(1)** Probe and tank experience equal **changes** in momentum (in opposite directions) **(1)** Statement that indicates that (total) energy is conserved **(1)** Kinetic energy of the system increases (so speed increases) **(1)** (Some) chemical energy converted to KE **(1)**	**6**
	Total for question	**6**

Question Number	Answer	Mark
3	(QWC – Work must be clear and organised in a logical manner using technical wording where appropriate) **Either** Initial momentum is zero Nucleus and alpha particle have equal momentum **(1)** (accept $m_n u_n = m_\alpha u_\alpha$ or $p_n = p_\alpha$) alpha particle and **(1)** nucleus move in opposite directions Mass of alpha **(1)** particle < mass of nucleus (therefore $v_n < v_\alpha$) **(1)** **Or** The nucleus and alpha particle exert an equal but opposite force on **(1)** each other. **(1)** Mass of alpha particle < mass of nucleus **(1)** Acceleration of nucleus < acceleration of alpha particle Force/acceleration acts for same time so Δv for nucleus is smaller for **(1)** nucleus	**4**
	Total for question	**4**

Question Number	Answer		Mark
4(a)	Use of eV conversion Use of $E_k = p^2/2m$ Or $E_k = 1/2mv^2$ **and** $p =$ mv $p = 1.4 \times 10^{-23}$ (N s) Example of calculation $p^2 = 2 \times 9.11 \times 10^{-31}$ kg $\times 1.6 \times 10^{-19}$ C $\times 700$ V $p^2 = 2.04 \times 10^{-46}$ N^2 s^2 $p = 1.4 \times 10^{-23}$ N s	**(1)** **(1)** **(1)**	**3**
4(b)	Use of $\lambda = h/p$ ecf from (a) $\lambda = 4.6 \times 10^{-11}$ m (show that value → 6.6×10^{-11} m)	**(1)** **(1)**	**2**
4(c)	Wavelengths need to be similar to the size of the atom **Or** reference to atomic spacing being similar to answer in (b)	**(1)**	**1**
	Total for question		**6**

Question Number	Answer		Mark
5(a)	Sum of momenta before (collision) = sum of momenta after (collision) **Or** the total momentum before (a collision) = the total momentum after (a collision) **Or** total momentum remains constant **Or** the momentum of a system remains constant	**(1)**	
	Providing no external/unbalanced/resultant force acts **Or** in a closed system	**(1)**	**2**
5(b)(i)	Use of equation(s) of motion sufficient to get answer	**(1)**	
	Initial speed = 1.1 (m s^{-1})	**(1)**	**2**
	<u>Example of calculation</u> s = (u +v)t/2 0.69 m = (u +0) × 1.3 s /2 u = 1.06 m s^{-1}		
5b)(ii)	Constant acceleration/deceleration (accept constant force)	**(1)**	
5(b)(iii)	Use of momentum = mv ecf v from (b)(i)	**(1)**	
	Calculates momentum after collision using correct mass	**(1)**	
	Speed of pellet = 117 or 124 or 129 (m s^{-1})	**(1)**	**3**
	<u>Example of calculation</u> Momentum after = (97.31 + 0.84) g × 1.06 m s^{-1} = 104 g m s^{-1} Momentum before = momentum after Speed of pellet = 104 g m s^{-1} / 0.84 g = 124 m s^{-1}		
***5(c)(i**	(QWC – Work must be clear and organised in a logical manner using technical wording where appropriate)		
	Mention of momentum	**(1)**	
	Pellet (bounces back so) has negative momentum /velocity **Or** momentum after = momentum of car - momentum of pellet	**(1)**	
	Pellet undergoes a bigger momentum/velocity change **Or** mass of car is less	**(1)**	**3**
5(c)(ii)	reference to greater horizontal momentum/force	**(1)**	**1**

5(d)	[The question says that the calculations are correct, the question is about the assumptions made. Do not credit a statement that the GPE is correct. MP1 is for the assumption that the KE after firing is the same as the max GPE. Do not credit energy loss due to air resistance or sound] $E_k \rightarrow E_{grav}$ of pendulum correct **Or** KE after collision is correct **(1)** E_k in collision not conserved **Or** not an elastic collision **Or** inelastic collision (do not credit just 'KE is lost') **(1)** Some energy becomes heat **(1)** E_k (of pellet before collision)is greater than 0.16J **(1)**	**4**
	Total for question	**16**

Question Number	Answer		Mark
6(a)	Use of ½ mv^2 and mgh (do not credit use of $v^2 = 2as$ since a not constant, scores 0/2) velocity = 0.77 (m s^{-1})	**(1)** **(1)**	**2**
6(b)	Use of mv Correct momentum conservation statement Speed = 0.53 m s^{-1} (accept 0.56 m s^{-1} from use of show that value) Assumption: no external forces/ no air resistance/ no force on pivot/negligible resistance Example of calculation 320 g × 0.77 m s^{-1} = (320 g × v) + (55g × 1.4 m s^{-1}) Speed of bat = 0.53 m s^{-1}	**(1)** **(1)** **(1)** **(1)**	**4**
6(c)	Use of $E_k = ½ mv^2$ (allow mass in g or kg) Correct calculation of E_k before and after (95, 45, 54 to any power of ten (see below) (If 0.8 m s^{-1} and 0.56 m s^{-1}, values are 102, 50 and 54) Elastic. Example of calculation Before impact E_k bat = ½ 0.320 kg 0.77^2 (m s^{-1})^2 = 0.095J After impact E_k bat = ½ 0.320 kg 0.53^2 (m s^{-1})^2 = 0.045 J E_k ball = ½ 0.055 kg 1.4^2 (m s^{-1})^2 = 0.054 J	**(1)** **(1)** **(1)**	**3**
6(d)	**Max 2** x measured to nearest cm uncertainty in x gives an uncertainty in GPE / speed (of ball) difficulty of measuring a moving object some energy to sound comments on $E_{(k)}$ after › before relates uncertainty to conclusion made in (c)	**(1)** **(1)** **(1)** **(1)** **(1)** **(1)**	**2**
	Total for Question		**11**

Question Number	Answer	Mark
7	QWC i and iii – Spelling of technical terms must be correct and the answer must be organised in a logical sequence Momentum conservation Total/initial momentum = 0 Momentum of slime equal momentum of bacteria (Bacteria) moves in <u>opposite</u> direction [backwards or forwards OK] OR Force on slime Equal and opposite force (on bacteria) Cause rate of change of momentum / $\Delta mv/t$ /ma to bacteria (Bacteria) moves in <u>opposite</u> direction [backwards or forwards OK]	 **(1)** **(1)** **(1)** **(1)** **(1)** **(1)** **(1)** **(1)** **(max 4)**
	Total for question	**4**