Mark Scheme

Q1.

Question Number	Acceptable Answer	Additional Guidance	Mark
	D $-0.60\ \text{kg m s}^{-1}$		**1**

Q2.

Question Number	Answer	Mark
	A	1

Q3.

Question Number	Answer	Mark
	D	1

Q4.

Question Number	Answer	Mark
	B	1

Q5.

Question Number	Acceptable answers	Additional guidance	Mark
	B as equal to total momentum before = 1×2−0.5×2	1.0	1
	A is the answer if each trolley had the same momentum C is the momentum of the second trolley only D is the answer if the two trolleys were travelling in the same direction		

Q6.

Question Number	Acceptable Answer	Additional guidance	Mark
	B	total kinetic energy is mv^2	**(1)**

Q7.

Question Number	Acceptable answers	Additional guidance	Mark
	B		1

Q8.

Question Number	Answer	Mark
	B	1

Q9.

Question number	Acceptable answers	Additional guidance	Mark
	Either • Calculate acceleration **(1)** • Use of $F = ma$ **(1)** • $F = 38$ N **(1)** **OR** • Calculate change in momentum **(1)** • Use of $F = \frac{\Delta mv}{\Delta t}$ **(1)** • $F = 38$ N **(1)**	Example of calculation: $F = \frac{0.06 \times 25}{0.04} = 37.5$ N	**3**

Q10.

Question Number	Acceptable Answer	Additional guidance	Mark
	An explanation that makes reference to: • correct reference to Newton's 3rd law (1) • balloon moves in opposite direction to the air (1) • applies Newton's 2nd law so that resultant force on balloon causes it to accelerate (1) OR applies Newton's 2nd law so that resultant force on balloon causes its momentum to change		**(3)**

Q11.

Question Number	Acceptable Answers	Additional guidance	Mark
	• Equate $E = mg\Delta h$ and $E=\frac{1}{2}mv^2$ (1) • Use of $p=mv$ (1) • p = 50 kg m s^{-1} (1)	Do not accept $v^2 = u^2 + 2as$ (because the hammer does not move in a straight line with constant acceleration) Example of calculation $mg\Delta h = \frac{1}{2}mv^2$ 31 kg × 9.81 ms^{-2} × 0.13 m = $\frac{1}{2}$ × 31 kg × v^2 $v = \sqrt{(2 \times 9.81\ \text{ms}^{-1} \times 0.13\ \text{m})}$ = 1.6 m s^{-1} p = 31 kg × 1.6 m s^{-1} = 49.6 kg m s^{-1}	3

Q12.

Question Number	Answer	Mark
*	(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**

Q13.

Question Number	Acceptable answers	Additional guidance	Mark
	• Glider 1 exerts this force on glider 2, so according to N3 (1) • Glider 2 will exert an (equal and) opposite force on glider 1 (1) • There is now a resultant force on glider 1 (1) • Glider 1 accelerates according to N1 **Or** glider 1 now moves to the left according to N1 (1)		4

Q14.

Question Number	Answer	Mark
*	(QWC – Work must be clear and organised in a logical manner using technical wording where appropriate) No external/unbalanced/resultant force so momentum of system is conserved **(1)** Rocket gains momentum in backward direction **(1)** Module gains equal amount of momentum in forward direction **(1)** Kinetic energy of the system increases **(1)** (Some) chemical energy converted to KE **Alternative mark scheme** if candidate presumes that the initial total momentum is zero (Max 4) **(1)** No external/unbalanced/resultant force so momentum of system is conserved **(1)** Rocket and module have equal amount of momentum and move in opposite directions (after separation) **(1)** Kinetic energy of the system increases **(1)** (Some) chemical energy converted to KE	**5**
	Total for question	**5**

Q15.

<table>
<tr><th>Question Number</th><th>Additional guidance</th><th colspan="2">Mark</th></tr>
<tr><td>*</td><td>
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Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.

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<tr><td>3 - 2</td><td>2</td></tr>
<tr><td>1</td><td>1</td></tr>
<tr><td>0</td><td>0</td></tr>
</table>
Indicative content

Sphere A applies a force to sphere B (on impact)
According to Newtons third law Sphere B will apply an (equal and) opposite force to Sphere A
This force opposes the motion of Sphere A
Sphere A decelerates, according to N2
The (resultant) force on sphere B accelerates B
The forces/impulse acting (on the spheres) are equal so the change in speeds/momentum are the same for each sphere.

</td><td colspan="2">
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</td><td>6</td></tr>
</table>

Q16.

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<tr><td>6</td><td>4</td><td>2</td><td>6</td></tr>
<tr><td>5</td><td>3</td><td>2</td><td>5</td></tr>
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</table>
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<tr><td></td><td>
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
</td><td></td><td>6</td></tr>
</table>

Q17.

Question Number	Answer	Mark
*	(QWC – Work must be clear and organised in a logical manner using technical wording where appropriate) **Max 6** **Fixed target** There is momentum before the collision so there must be momentum after the collision. (1) So particle(s) created must have some kinetic energy (1) So not all KE converted to mass (1) **Colliding beams** (If particles have the same mass and speed), total initial momentum is zero (1) Momentum after collision will be zero (1) If one stationary particle is created (1) All of the kinetic energy of the particle is converted to mass (1)	6
	Total for question	**6**

Q18.

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<tr><td>1</td><td>1</td></tr>
<tr><td>0</td><td>0</td></tr>
</table>

Indicative content:

Newton's 3rd law pair of forces must be of the same type
Or Newton's 3rd law pair of forces must act on different bodies
The two forces mentioned are not a 3rd Law pair
Or gravity is not a good description of force
The lift on the plane should be paired with the push of the plane on the air
Or the gravitational force of Earth on plane should be paired with the gravitational force of plane on Earth.
If the vertical resultant force is zero the plane will not accelerate vertically
So the plane could be 'at rest' or moving with uniform velocity in the vertical direction
There must be some horizontal motion so plane can't be in same place

</td>
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Linkage Marks

IC points 1 – 3
Two of these points could score one linkage mark

IC points 4 – 6
Two of these points could score one linkage mark
</td>
<td>6</td>
</tr>
</table>

Q19.

Question Number	Additional guidance		Mark
	• Measurement of change in height of Sphere A (1) • actual height = $\frac{\text{image height} \times 11}{4.8}$ (1) • Use of E_k gained = E_{grav} lost to determine v (1) • Use of $p = mv$ (1) • $p_A = 0.025$ kg m s^{-1}	Initial decrease in height from photo = 2.9 ± 0.1 cm Height of frame in photo = 4.8 ± 0.1 cm MP2-4 award even if measurement for the height is out of range MP3 use of equation of motion scores 0 Example of calculation $h_A = \frac{2.9 \text{ cm} \times 11 \text{ cm}}{4.8 \text{ cm}} = 6.6$ cm ½× 0.022 kg × v_A^2 = 0.022 kg × 9.81 N kg^{-1} × 6.6 × 10^{-2} m $v_A = 1.14$ m s^{-1} $p_A = 0.022$ kg × 1.14 m s^{-1} = 0.025 kg m s^{-1} Accept p_A in range 0.024 – 0.026 kg m s^{-1}	5

Q20.

Question Number	Acceptable answers		Additional guidance	Mark
(i)	• Use of momentum = mv (1) • See component(s) in x direction (1) • Uses momentum conservation (1) • $u = 1.6$ (m s^{-1}) (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)

Question Number	Acceptable answers		Additional guidance	Mark
(ii)	• Use of $E_k = ½ mv^2$ (1) • Value of Initial $E_k = 9.0\times10^{-3}$ (J) and Final $E_k = 6.4\times10^{-3}$ (J) (Show that value gives Initial $E_k = 1.42 \times10^{-2}$ (J) allow ecf from (b)(i)) (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)

Q21.

Question Number	Answer		Mark
*	(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

Q22.

Question Number	Acceptable Answer		Additional Guidance	Mark
(a)(i)	• use of $p = mv$	(1)	Example of calculation p = 300 kg × 7 m s^{-1} p = 2100 kg m s^{-1} 2100 kg m s^{-1} = (300 kg + 250 kg) v v = 3.8 m s^{-1}	**(3)**
	• use of conservation of momentum	(1)		
	• v = 3.8 m s^{-1}	(1)		

Question Number	Acceptable Answer		Additional Guidance	Mark
(a)(ii)	• use of $E_k = ½ mv^2$	(1)	Example of calculation E_k = ½ × 550 kg × (3.8 m s^{-1})^2 E_k = 3970 J 3970 J = F × 1.3 m F = 3050 N Allow error carried forward for velocity from (a)(i)	**(3)**
	• use of $W = Fd$	(1)		
	• F = 3100 N	(1)		

Question Number	Acceptable Answer	Additional Guidance	Mark
(b)	no external forces acted on the cars/system		**(1)**

Q23.

Question Number	Acceptable answers	Additional guidance	Mark
(a)(i)	• Use of $\lambda = h/p$ and $v = f\lambda$ **(1)** • Momentum of photon = 3.3 × 10^{-27} (N s) **(1)**	Example of calculation Momentum of photon = $p = hf/c$ = 6.63 × 10^{-34} J s × 1.5 × 10^{15} Hz ÷ 3.00 × 10^{8} m s^{-1} = 3.315 × 10^{-27} N s	**2**

Question Number	Acceptable answers	Additional guidance	Mark
(a)(ii)	• Momentum transfer = 6.6 × 10^{-27} (N s) **(1)**	Ecf momentum from (i) in parts (a)(ii) and (c)	**1**

Question Number	Acceptable answers	Additional guidance	Mark
(b)(i)	• Use of $hf = \varphi + ½ mv^2_{max}$ **(1)** • Use of $E_K = ½ mv^2$ **(1)** • $v = 8.4 \times 10^5$ (m s^{-1}) **(1)**	Example of calculation $hf = \varphi + ½ mv^2_{max}$ hf = 6.63 × 10^{-34} J s × 1.5 × 10^{15} Hz = 9.95 × 10^{-19} J $hf - \varphi$ = 9.95 × 10^{-19} J − 6.7× 10^{-19} J = 3.25 × 10^{-19} J 3.25 × 10^{-19} J = ½ × 9.11 × 10^{-31} kg × v^2 v = 8.4 × 10^5 m s^{-1}	**3**

Question Number	Acceptable answers	Additional guidance	Mark
(b)(ii)	• Use of $p = mv$ **(1)** • Momentum of photoelectron = 7.7 × 10^{-25} N s **(1)**	Example of calculation p = 9.11 × 10^{-31} kg × 8.4 × 10^5 m s^{-1} Momentum of photoelectron = 7.68 × 10^{-25} N s MP2: Using show that value p = 7.3 × 10^{-25} N s	**2**

Question Number	Acceptable answers	Additional guidance	Mark
(c)	An explanation that refers to the following points: • the change in momentum of the graphene oxide is the same as the change in momentum of the photoelectron **(1)** • so the (change in) momentum is much larger for the photoelectron than for the reflected photon **(1)**	Accept converse statement and answer that is consistent with candidate's values in (a) and (b)	**2**

Q24.

Question Number	Answer	Mark
* (a)	**(QWC – work must be clear and organised in a logical manner using technical terminology where appropriate)** **Max 5** Solid (CO_2) exerts a force on the gas (CO_2) **(1)** N3 means (gas exerts) a force on the solid/X **(1)** Force is in opposite direction on the solid/gas **(1)** There is a resultant/unbalanced force (on the solid) **(1)** N2/1 means the (solid) accelerates (accept changes velocity/speed) **(1)** Rapid because mass/friction is small **(1)** (No mark for a statement of Newton's Laws)	**5**
(b)	More than one jet **(1)** Zero/no resultant force **Or** forces balanced/cancel **(1)**	**2**
	Total for question	**7**

Q25.

Question Number	Acceptable Answer	Additional Guidance	Mark
(a)	• use of $v^2 = u^2 + 2as$ **(1) OR** use of ½ $mv^2 = mgh$ **(1)** • initial speed = 7.0 m s^{-1} **(1)**	Example of calculation: $v = 0$ $a = -9.81$ m s^{-1} $s = 2.5$ m $u^2 = -2as$ $u^2 = -(2 \times -9.81$ m $s^{-1} \times 2.5$ m$) = 49$ m^2 s^{-2} $u = 7.0$ m s^{-1} Alternative calculation: ½ $v^2 = gh$ v = √(2gh) = √(2 x 9.81 x 2.5) = = 7.0 m s^{-1}	**2**
(b)	• use of trig function to find v vertical **(1)** • use of trig function to find v horizontal **(1)** • use of equation of motion to find time of flight **(1)** • use of equation of motion to find distance **(1)** • horizontal distance = 2.7 m **(1)**	Example of calculation vertical velocity = 6.5 m s^{-1} sin 20 = 2.22 m s^{-1} time of flight using $v = u + at$ -2.22 m s^{-1} = 2.22 m s^{-1} + (-9.81 m $s^{-1} \times t$) $t = 0.45$ s horizontal velocity = 6.5 m s^{-1} cos 20 = 6.11 m s^{-1} horizontal distance using $s = ut$ $s = 6.11$ m $s^{-1} \times 0.45$ s $s = 2.7$ m	**5**
(c)(i)	• use of $p=mv$ **(1)** • correctly applies conservation of momentum **(1)** • $v = 14.8$ m s^{-1} **(1)**	Example of calculation: momentum of lid = − momentum of canister 1.6 g × v = 4.3 g × 5.5 m s^{-1} $v = 14.8$ m s^{-1}	**3**
(c)(ii)	An explanation that makes reference to: • no unbalanced force on dry ice **(1)** • so no acceleration according to Newton's First Law **(1)**	MP2 is dependent on MP1 Allow suitable reference to Newton's Second Law for MP2	**2**

Q26.

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)**

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<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>
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</table>

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

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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 OR Δp for one puck = $-\Delta p$ for the other puck, so momentum is conserved (1)

(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)		

Q27.

Question Number	Answer		Mark
(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**
(b)(i)	Use of equation(s) of motion sufficient to get answer Initial speed = 1.1 (m s^{-1}) Example of calculation $s = (u + v)t/2$ 0.69 m = $(u + 0) \times 1.3$ s /2 u = 1.06 m s^{-1}	**(1)** **(1)**	**2**
(b)(ii)	Constant acceleration/deceleration (accept constant force)	**(1)**	**1**
(b)(iii)	Use of momentum = mv ecf v from (b)(i) Calculates momentum after collision using correct mass Speed of pellet = 117 or 124 or 129 (m s^{-1}) Example of calculation 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}	**(1)** **(1)** **(1)**	**3**
***(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**
(c)(ii)	reference to greater horizontal momentum/force	**(1)**	**1**

(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**