Mark Scheme

Q1.

Question Number	Answer	Mark
	A is the correct answer B is incorrect because this is an SI unit of force C is incorrect because this is an SI unit of acceleration D is incorrect because units of momentum are usually either kg m s^{-1} or N s	**1**

Q2.

Question Number	Answer	Mark
	The only correct answer is C as the velocity is changing (due to the direction changing) and N2 describes a resultant force (due to the gravitational force of the earth) causing a change in velocity **A** *is not the correct answer as the velocity is changing* **B** *is not the correct answer as the velocity is changing and N2 describes a changing velocity due to unbalanced forces* **D** *is not the correct answer as N2 describes a changing velocity due to unbalanced forces*	(1)

Q3.

Question Number	Answer	Mark
	The only correct answer is B ($\frac{2}{3}\ v$) A is not correct because the momentum and mass of the ball should not be multiplied together C is not correct because the mass of the ball should not be divided by the momentum of the ball D is not correct because the momentum and mass of the cricket ball should not be multiplied together	**1**

Q4.

Question Number	Answer	Mark
	The only correct answer is B (3*p*) A is not correct because the change in velocity is the same for both objects so the increase in momentum of S is greater than that of R C is not correct because S does not double its speed D is not correct because S moves 1.5 times faster than at the start and has twice the mass of R	**1**

Q5.

Question Number	Answer	Mark
	D is the correct answer A is not the correct answer as it contradicts Newton's Third Law. B is not the correct answer as it also contradicts Newton's Third Law. C is not the correct answer as the force of Y on X is in the opposite direction to the velocity of X.	**(1)**

Q6.

Question Number	Answer		Mark
(a)	A exerts a force on B **and** B exerts an equal (magnitude) and opposite (direction) force on A	(1)	
	OR		
	The gliders exert equal (magnitude) and opposite (direction) forces on each other	(1)	1
(b)	Use of $p = mv$	(1)	
	Total momentum = 0.026 kg m s^{-1} (to the right) **Or** Final velocity = 0.074 m s^{-1} (to the right) **Or** Initial momentum of A = 0.048 kg m s^{-1} (to the right) **and** initial momentum of B = 0.022 kg m s^{-1} (to the left)	(1)	
	So after the collision the gliders will move to the right and the prediction is not correct (dependent on a valid calculation for MP2)	(1)	3
	<u>Example calculation</u> If a momentum to the right is positive, then Total momentum = 0.15 kg × 0.32 m s^{-1} − 0.20 kg × 0.11 m s^{-1} = 0.048 kg m s^{-1} − 0.022 kg m s^{-1} = 0.026 kg m s^{-1} So total momentum is to the right so the prediction is not correct		
	Total for question		**4**

Q7.

Question Number	Answer	Mark
(a)	the total momentum before (a collision) = the total momentum after (a collision) **Or** Sum of momentum values before (collision) = sum of momentum values after (collision) **Or** total momentum remains constant **Or** **(1)** the momentum of a system remains constant Provided no external/unbalanced/resultant force acts (on the system) **Or** **(1)** in a closed/isolated system	**2**
(b)	Use of $p = m\,v$ **(1)** Uses conservation of momentum **(1)** Velocity = − 4.6 m s^{-1} **(1)** <u>Example of calculation</u> 2.7 kg × 10 m s^{-1} = 2.7 kg × v + 7.9 kg × 5.0 m s^{-1} v = (27.0 − 39.5) kg m s^{-1} ÷ 2.7 kg = −4.6(3) m s^{-1}	**3**
	Total for question	**5**

Q8.

Question Number	Answer		Mark
(a)	Total momentum before (a collision) = total momentum after (a collision) **Or** total momentum remains constant	(1)	
	When no external force acts **Or** When no resultant force acts on the system **Or** In a closed / isolated system	(1)	2
(b)(i)	Momentum is mass ×velocity **and** after the collision the mass (that is moving) is double the original value.	(1)	
	(because velocity is half its original value) momentum remains the same so the law is obeyed (dependent on MP1)	(1)	2
	OR		
	Initial momentum of A is equated to final momentum of A plus final momentum of B	(1)	
	Shows that MP1 is consistent with final velocity = half initial velocity and concludes that the law is obeyed (dependent on MP1)	(1)	
(b)(ii)	(The gliders accelerate in opposite directions because) the magnetic forces are equal in size and opposite in direction **Or** (The gliders accelerate in opposite directions because) the magnetic forces form a Newton's 3rd law pair	(1)	
	So the velocity of one glider increases and the velocity of the other decreases (by the same amount) **Or** So the resultant force on the system is zero **Or** The magnetic forces are not external forces	(1)	2
	Total for question		6

Q9.

Question Number	Answer		Mark
(a)	Use of $(\Delta)E_{grav} = Fd$ **Or** Use of $E_k = (\Delta)E_{grav}$ **AND** Use of $v^2=u^2+2as$ with $a = -\frac{F}{m}$ Gradient = $\frac{mg}{F}$ **Or** $\frac{d}{h} = \frac{mg}{F}$ <u>Example of calculation</u> $mgh = Fd$ $\frac{d}{h} = \frac{mg}{F}$	(1) (1)	**(2)**
(b)	$u = \sqrt{2gh}$ (Do not allow if suvat used with $a=g$) Use of $p = mv$ $m_1u = (m_1 + m_2)v$ (either seen or used) (Do not allow if there is an m_2u term unless $u=0$) Some working leading to the correct expression **AND** statement that the student is correct. <u>Example of calculation</u> $mgh = ½ mv^2$ $v = \sqrt{2gh}$ $m\sqrt{2gh} = 2mv$ $v = \frac{\sqrt{2gh}}{2} = \sqrt{\frac{gh}{2}}$	(1) (1) (1) (1)	**(4)**
	Total for question		**6**

Q10.

Question Number	Answer	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 following 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

	Marks
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: IC1 Balloon exerts a (backwards) force on the air IC2 By N3 the air exerts an opposite (forwards) force on balloon IC3 The forward force on the balloon is greater than resistive forces IC4 By N2 the resultant force causes acceleration IC5 As speed increases forces change until resistive force equals forward force IC6 By N1 resultant force equals zero so acceleration equals zero (at maximum speed)	6
	Total for question	**6**

Q11.

Question Number	Answer	Mark
(a)	Sum of momenta before (collision) = sum of momenta after (collision) **Or** Total momentum before (a collision) = total momentum after (a collision) **Or** Total momentum remains constant **Or** The momentum of a system remains constant (1) Provided no external/unbalanced/resultant force acts (on the system) **Or** in a closed/isolated system (1)	2
(b)	Use of $p = m\,v$ (1) Momentum before collision = 810 N s **and** after collision = 780 N s **Or** Expected velocity = 6.5 m s^{-1} (1) Correct conclusion based on comparison of candidate's momenta/speeds (1) <u>Example of calculation</u> Momentum before collision: 65 kg × 5.5 m s^{-1} + 60 kg × 7.5 m s^{-1} = 807.5 N s Momentum after collision: (65 + 60) kg × 6.2 m s^{-1} = 775.0 N s 775 ≠ 808 ∴ momentum not conserved	3
(c)	<u>Forces</u> acted between skaters (during the collision) (1) **Or** External forces [accept friction (between skates and ice)] act on the skaters (during the collision) <u>Work</u> done (by forces) during the collision was not recovered **Or** (1) <u>Work</u> done (by forces) during the collision was dissipated **Or** <u>Work</u> done (by forces) transfers (kinetic) energy to thermal energy [accept "heat"]	2
	Total for question	7

Q12.

Question Number	Answer	Mark
(a)	Use of $p = mv$ (1) Use of momentum conservation (1) $v = 0.048$ (m s^{-1}) (1) <u>Example of calculation</u> Initial momentum = 0.165 kg × 0.739 m s^{-1} = 0.122 N s 0.165 kg × 0.691 m s^{-1} + 0.165 kg × v = 0.122 N s $v = \frac{0.122 \text{ N s} - 0.114 \text{ Ns}}{0.165 \text{ kg}} = 0.048 \text{ m s}^{-1}$	3
(b)	Use of $E_k = ½ m v^2$ (1) Decrease in $E_k = 5.4 \times 10^{-3}$ (J) (ecf from 15(a)) (1) <u>Example of calculation</u> A: final $E_k = 0.5 \times 0.165 \text{ kg} \times (0.048 \text{ m s}^{-1})^2 = 1.90 \times 10^{-4}$ J B: final $E_k = 0.5 \times 0.165 \text{ kg} \times (0.691 \text{ m s}^{-1})^2 = 3.94 \times 10^{-2}$ J Total final $E_k = 3.94 \times 10^{-2} \text{ J} + 1.90 \times 10^{-4} \text{ J} = 3.96 \times 10^{-2}$ J Decrease in $E_k = 4.5 \times 10^{-2} - 3.96 \times 10^{-2} = 5.40 \times 10^{-3}$ J	2

(c)	(By Newton's third law) ball B exerts a force equal (in magnitude) and opposite (in direction) on ball A (1) (By Newton's first / second law), resultant force on A causes A to decelerate (1) To score **2** marks, there must be a reference to Newton's second law or Newton's third law.	2
	Total for question	7

Q13.

Question Number	Answer		Mark
(a)	Use of $p = m\,v$ Use of momentum conservation $v = 0.04\ \text{m s}^{-1}$ Towards O , away from S, to left (dependent on MP3) <u>Example of Calculation</u> $1350\ \text{kg} \times 0.82\ \text{m s}^{-1} + 2950\ v - 2100\ \text{kg} \times 0.58\ \text{m s}^{-1} = 0$ $v = (1218 - 1107)\ \text{kg m s}^{-1} \div 2950\ \text{kg} = 0.0376\ \text{m s}^{-1}$	(1) (1) (1) (1)	4
(b)(i)	The rocket motor exerts a force on the gases, so the gases exert a force on the rocket motor The forces are equal and opposite according to Newton's third law (dependent on MP1) So there is a resultant/net/unbalanced force on the descent module, which accelerates according to Newton's second law (accept Newton's first law)(independent mark)	(1) (1) (1)	3
(b)(ii)	Use of $v = u + at$ to find a Use of $\Sigma F = m\,a$ $\Sigma F = 3.4 \times 10^2\ \text{N}$ <u>Example of Calculation</u> $a = 0.58\ \text{m s}^{-1} \div 5\ \text{s} = 0.116\ \text{m s}^{-2}$ $\Sigma F = m\,a = 2950\ \text{kg} \times 0.116\ \text{m s}^{-2} = 342.2\ \text{N}$	(1) (1) (1)	3
	Total for question		**10**

Q14.

Question Number	Answer		Additional Guidance	Mark
(a)	(By Newton's second law), Stone A and stone B accelerate in opposite directions (for the same time) So the momentum of A decreases and the momentum of B increases by the same amount **Or** So change of momentum for each stone is the same size but in the opposite direction	**(1)** **(1)**	Allow the velocity of stone A decreases and the velocity of stone B increases Allow change in momentum = force × time (and force and time are the same for both stones)	**2**
(b)	Use of $E_k = \frac{1}{2}mv^2$ Use of $p = mv$ Use of conservation of momentum Final momentum of A = 4.1 kg m s^{-1} 4.1 (kg m s^{-1}) < 5.5 (kg m s^{-1}) so stone A will not slide past the target **Or** Comparison of calculated value of final momentum of A with 5.5 (kg m s^{-1}) and consistent conclusion	**(1)** **(1)** **(1)** **(1)** **(1)**	<u>Example of calculation</u> $u_A = \sqrt{\frac{2 \times 3.8\ \text{J}}{18\ \text{kg}}} = 0.650\ \text{m s}^{-1}$ $p_{A(before)} = 18\ \text{kg} \times 0.650\ \text{m s}^{-1} = 11.7\ \text{kg m s}^{-1}$ $p_{B(after)} = 17\ \text{kg} \times 0.45\ \text{m s}^{-1} = 7.65\ \text{kg m s}^{-1}$ $11.7\ \text{kg m s}^{-1} - 7.65\ \text{kg m s}^{-1} = 4.05\ \text{kg m s}^{-1}$ $4.05\ \text{kg m s}^{-1} < 5.5\ \text{kg m s}^{-1}$ so stone A will not slide past the target	**5**
	Total for question			**7**

Q15.

Question Number	Answer		Mark
(a)(i)	Use of $p = m\,v$ Use of conservation of momentum $m = 151$ (kg) Use of $F = \Delta p / \Delta t$ scores MP1 and MP2 <u>Example of calculation</u> $p = 250\ \text{kg} \times 2.10\ \text{m s}^{-1} = 250\ \text{kg} \times 1.15\ \text{m s}^{-1} + m \times 1.57\ \text{m s}^{-1} = 525.0\ \text{kg m s}^{-1}$ $m = (525.0 - 287.5\ \text{N s})\ \text{kg m s}^{-1} \div 1.57\ \text{m s}^{-1}$ $= 237.5\ \text{kg m s}^{-1} \div 1.57\ \text{m s}^{-1} = 151.3\ \text{kg}$	(1) (1) (1)	3
(a)(ii)	No external horizontal forces acted on either car during the collision.	(1)	1
(a)(iii)	Use of $a = \Delta v / \Delta t$ Use of $\Sigma F = ma$ $\Sigma F = 1.76 \times 10^2$ N (ecf from (a)(i)) <u>Example of calculation</u> average acceleration $= 1.57\ \text{m s}^{-1} \div 1.35\ \text{s} = 1.16\ \text{m s}^{-2}$ $\Sigma F = 151.3\ \text{kg} \times 1.16\ \text{m s}^{-2} = 1.76 \times 10^2$ N	(1) (1) (1)	3
(b)	P exerts a force on Q so Q exerts a force on P Due to N3 forces are equal and opposite in direction Resultant force on P opposite to direction of motion so according to N2, P decelerates	(1) (1) (1)	3
	Total for question		**10**

Q16.

Question Number	Answer		Mark
(a)(i)	• Use of $\rho = \frac{m}{V}$ • Use of $A = \pi r^2$ • Use of volume in 1 second = cross section area × speed • Speed = 37.1 (m s^{-1}) Example of calculation $\frac{V}{t} = \frac{300 \text{ kg s}^{-1}}{1030 \text{ kg m}^{-3}} = 0.291 \text{ m}^3\text{s}^{-1}$ $A = \pi \times 0.05^2 = 7.85 \times 10^{-3}$ m^2 Speed = 0.291 m^3 s^{-1}/ 7.85 × 10^{-3} m^2 = 37.1 m s^{-1}	(1) (1) (1) (1)	4
(a)(ii)	• Use of $p = mv$ • Rate of change of momentum = 1.1 × 10^4 kg m s^{-2} (ecf from (a)(i)) Example of calculation mass × speed = 300 kg × 37.1 m s^{-1} = 1.11 × 10^4 kg m s^{-2}	(1) (1)	2
(b)	• Pump applies a (forward) force to the water. • By Newton 3, water applies an (equal and) opposite/backward force to the pump **Or** By Newton 3, water applies a force to the pump in the opposite direction to the (flow of) water.	(1) (1)	2
(c)	• Initially (speed is constant because) drag force = forward force • Turning on pump gives resultant force backwards, so boat slows. • Drag force becomes less (as boat slows) until forces balance again.	(1) (1) (1)	3
	Total for question		**11**

Q17.

Question Number	Answer		Mark
(a)	A value of v and corresponding value of t read from graph Use of $a = \frac{\Delta v}{\Delta t}$ using values of t between 14 ms and 50 ms or using a value of $\Delta t \leq 36$ ms. Average acceleration = 86 m s^{-2} Example of calculation $a = \frac{2.85 \text{ m s}^{-1}}{48 \times 10^{-3} \text{ s} - 15 \times 10^{-3} \text{ s}} = 86.3 \text{ m s}^{-2}$	(1) (1) (1)	3

* (b)	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.	

IC points	IC mark	Max linkage mark	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

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

IC1 The ball applies a force to the skittle.
IC2 The skittle applies a force to the ball.
IC3 Newton's 3rd Law means that the forces (on the skittle and the ball) are equal (in size) and opposite (in direction).
IC4 There is a resultant force acting on the skittle / ball.
IC5 The skittle / ball accelerates according to Newton's second law.
IC6 The skittle accelerates (to the left) and the ball decelerates.

6

(c)	Use of $p = mv$	(1)	
	Use of total momentum before collision = total momentum after collision	(1)	
	Mass of ball = 0.78 kg	(1)	**3**
	<u>Example of calculation</u> $m \times 7.2\ \text{m s}^{-1} = m \times 1.6\ \text{m s}^{-1} + 1.4\ \text{kg} \times 3.1\ \text{m s}^{-1}$ $m = \dfrac{1.4\ \text{kg} \times 3.1\ \text{m s}^{-1}}{7.2\ \text{m s}^{-1} - 1.6\ \text{m s}^{-1}} = 0.775\ \text{kg}$		
	Total for question		**12**