Mark scheme

Question			Answer/Indicative content	Marks	Guidance
1			the rocket exerts a (backwards) force on the (hot) gas (so) the gas exerts a (forwards) force on the rocket (this forwards) force must be greater than the weight of the rocket / there is a resultant force (which causes acceleration / a change in momentum)	B1 B1 B1	**Ignore** incorrect numbering or general statements of Newton's Laws throughout **Allow** engine for rocket **Allow** (burning) fuel for gas but **not** air Note that 'rocket expels gas backwards' is in the stem and so gains no credit **Allow** engine for rocket **Allow** gas pushes the rocket forwards **Allow** net or unbalanced for resultant **<u>Examiner's Comments</u>** It was expected that candidates would use, rather than simply state, Newton's laws of motion in order to explain why the rocket accelerates. Most candidates were able to state, 'for every action there is an equal and opposite reaction' or even 'if A exerts a force on B, then B exerts and equal and opposite force on A'. However, few extended that to 'if the rocket exerts a force on the gas (backwards) then the gas will exert a force on the rocket (forwards)'. Even fewer went on to explain that, in order for the rocket to accelerate, this force must be greater than the weight of the rocket in order for there to be a resultant force (forwards).
			Total	**3**	
2	a	i	Curve starts at (0,0) with gradient decreasing to a maximum value 30 on vertical axis matching highest point of candidate's line	B1 B1	Accept horizontal asymptote NB ignore candidate's response after their line reaches 30 (m/s) **<u>Examiner's Comments</u>** Most candidates used the grid effectively to put a suitable scale on the speed axis. They also communicated that the maximum speed was 30 m s^{-1}. Many candidates also got the shape of the curve correct, which starts with maximum gradient and then flattens out.

		ii	Resistive force increases (with speed) Zero net or zero resultant force	B1 B1	Allow drag / (air) resistance / friction for 'resistive force' Allow resistive force = component of weight down the slope NOT simply idea of resistive force = weight **<u>Examiner's Comments</u>** While many candidates appreciated that the car reached a maximum speed because the resultant force was zero, some contradicted this by saying that the weight = drag (as it would be in vertical motion) or something else incorrect. Far fewer candidates stated that the drag increases with speed effectively. Quoting the given expression $F = kv^2$ was deemed insufficient. **Examination Tip** Repeating information given in the question is rarely creditworthy by itself.
		iii	Component of weight down slope = 9300 sin 5° Re-arrange to (k=)$F \div v^2$ (k=)810 ÷ 900 = 0.9…	M1 M1 A1	Allow 810 or 811 seen Allow substitutions for variables Mark is for substitution <u>and</u> candidate's value seen **<u>Examiner's Comments</u>** As this question is a 'show that', all steps were required. Many candidates omitted the rearrangement stage, restricting their maximum score for this item to 1 mark. This approach was consistent throughout the paper for this type of question. **Examination Tip** Make sure that all steps of working are presented in 'show that' questions, especially the step that shows the relevant quantity as the subject of the equation. Always show your evaluation to at least 1 more significant figure than that shown in the question.
	b		evidence of substitution of $F=kv^2$ into $P = Fv$ $v = (P \div k)^{1/3}$ v = 44 (m s^{-1})	C1 C1 A1	e.g. $P = kv^3$, $P = (kv^2)\ v$, etc Allow use of k = 1 which gives 42 Allow answer within range 36 to 53 **<u>Examiner's Comments</u>** The key idea here is that the force from the engine (given by $F = P / v$) will equal the resistive forces ($F = kv^2$) when the car is at maximum speed. Candidates

					could choose which value of k they used here, either k = 1 from the question data or the value of k from the previous item. This gives an acceptable range of speeds as stated in the mark scheme.
	c		Power is proportional to the speed cubed / Max speed is proportional to the cube root of max power / power proportional to speed x kv^2 Valid reference to the cube root of 2 increase in velocity for double power / Valid reference to factor of 8 increase in power for double the velocity	B1 B1	NB cube root of 2 is 1.2599… e.g. 1.26 × 44 = 55 (m s^{-1}) **Examiner's Comments** Even if they couldn't complete the calculation in the previous item, candidates needed to be able to state the idea qualitatively for the first mark. No further calculations were required, except the correct answer that the maximum speed would increase by a factor of cube root (2).
			Total	**12**	
3	a		**Net** force is proportional to rate of change of momentum	B1	Allow "equal to" for 'proportional' Allow use of resultant or total for net Allow symbols provided they are defined. NOT force = mass x acceleration **Examiner's Comments** Most candidates selected the right law of motion to state although a reasonable fraction missed out something vital. Often than was that the idea of resultant force. **Misconception** Common misconception that F = ma is Newton's second law, whereas it's a special case.
	b	i	Horizontal = 43 (.3) (m s^{-1}) Vertical = 25 (m s^{-1})	B1 B1	ignore sign Allow answers in incorrect order for 1 mark MAX Allow H = 7.7 (m s^{-1}), V = −49.4 (m s^{-1}) 1 mark MAX **Examiner's Comments** Most candidates got this correct. Some scored a single mark for confusing sine and cosine but otherwise completing the calculation correctly. **Examination Tip**

					Make sure to check whether your calculator should be in degrees or radians mode. Also, practise which trigonometric function to use. If in doubt, draw a labelled right-angled triangle to help identify the correct function.
		ii	Correct application of N3L Plus ONE from: (Direction of) momentum of air has changed or direction of air flow has changed There is a force on the air (from the model)	B1 B1 B1	force on air is equal (and opposite) to force on model **Examiner's Comments** The key idea here was Newton's third law, with credit for some supporting information.
		iii	$F = \frac{\Delta p}{\Delta t}$ *F* = 35 × 25 (divided by 1) *F* =880 (N)	C1 C1 A1	ecf candidate's vertical velocity in (i) Allow 875 Allow 870 **Examiner's Comments** Answers that clearly used F = ma with the acceleration of 25 ms^{-2} were deemed wrong Physics (as in previous series). Error Carried Forward (ECF) was clearly applied here also.
			Total	**8**	
4			**A**	1	**Examiner's Comments** This is a conservation of momentum question. The momentum of each object is 10 kg m s^{-1}. The combined momentum has two components at right angles to each other of 10 kg ms-1. The magnitude of this momentum is √(200). To find the speed, divide this by 2.0 kg, giving 7.1 m s^{-1}, so the answer is A.
			Total	**1**	
5			**C**	1	**Examiner's Comments** Many candidates correctly applied understanding of inelastic collisions that momentum is conserved, but the kinetic energy is not conserved to give the correct answer C.
			Total	**1**	
6			**B**	1	**Examiner's Comments** Many candidates correctly identified the correct response, B, by applying their understanding that an interaction pair of forces according to Newton's third law

					do not act on the same body. The most common distractor answer was D. **Misconception** A common misconception when applying Newton's third law of motion is that the interaction pair of forces are acting on the same body and/or that the pair of forces are different types of forces. Newton's third law states: *Whenever **two** bodies interact, the forces they exert on each other are equal in size, act in opposite directions, and are of the **same** type.* For example, if object A exerts a force on object B, then object B exerts an **equal** and **opposite** force on object A and if object A exerts a **gravitational force** on object B, then object B exerts an equal and opposite **gravitational force** on object A. Most candidates correctly identified that the pair of forces are equal in magnitude and opposite in direction but display a common misconception that the two forces are different and that they act on the same one body.
			Total	**1**	
7	a		(Net) force is (proportional to) the rate of change of momentum	B1	**Allow** $F = \frac{\Delta p}{\Delta t}$ with symbols defined **Ignore** *F=ma* (special case) **<u>Examiner's Comments</u>** The majority of high scoring candidates stated that the net force is directly proportional to the rate of change of momentum. Some candidates gave the definition in symbols - this approach gained credit provided each symbol was identified. Lower scoring candidates often gave the special case of Newton's second law (force = mass × acceleration) which did not gain credit.
	b	i	(0.16 × 20 =) 3.2 N s or kg m s^{-1}	B1 B1	**<u>Examiner's Comments</u>** This was generally well answered. Candidates who calculated the impulse correctly usually gave the correct unit. Both N s and kg m s^{-1} were given. A significant minority of candidates calculated the force (97).

		ii	$\left(\frac{3.2}{0.033}=\right)$97 (N)	B1	**Allow ECF** from **(b)(i)** **<u>Examiner's Comments</u>** The majority of candidates understood that impulse = change in momentum and correctly divided their answer to Question 2 (b) (i) by 0.033 s.
	c	i	(For a perfectly elastic collision) <u>kinetic</u> energy is conserved	B1	**Allow** (total) <u>kinetic</u> energy before (the collision) is equal to the (total) <u>kinetic</u> energy after (the collision) **<u>Examiner's Comments</u>** Many candidates correctly stated that the kinetic energy in the collision is conserved. Where credit was not gained, it was invariably due to candidates stating that 'energy was conserved' without explicitly stating kinetic energy.
		ii	Conservation of momentum: 0.16 × 20 = (*m* + 0.16) × 8 + 0.16 × -12 (*m* + 0.16) × 8 = 5.12 or (*m* + 0.16) = 0.64 0.48 (kg) OR Conservation of kinetic energy: ½ × 0.16 × 20² = ½ × (*m* + 0.16) × 8² + ½ × 0.16 × (−)12² 32 × (*m* + 0.16) = 20.48 or 0.64 0.48 (kg)	C1 C1 A1 C1 C1 A1	**Allow ECF** from **(b)(i)** for this method **Allow** 0.16 × 20 = (*M*) × 8 + 0.16 × -12 **Allow** 8*M* = 5.12 **Note** 0.64 gains two marks 32 = 32 × (*m* + 0.16) + 11.52 **Allow** 32*M* = 20.48 **Note** 0.64 gains two marks **<u>Examiner's Comments</u>** High scoring candidates generally scored well on this question. Most candidates attempted to determine *m* by using a conservation of momentum method. A small minority correctly used a conservation of kinetic energy method. The common error for the conservation of momentum method was to have an incorrect sign. A few candidates did not allow for the original mass of the puck.
			Total	**8**	
8	a		22.3 cos 84 (= 2.33) 2.33	M1 A0	**ALLOW** 22.3 sin 6 **<u>Examiner's Comments</u>**

					Most candidates clearly showed how the initial velocity of the ball could be resolved into its horizontal component. Most candidates used cos 84° although there was a significant minority who correctly used sin 6°.
	b		$v_v^2 = 2.33^2 + 2 \times 9.81 \times 2.4$ $v_v = \sqrt{52.517}$ OR 7.247 7.25	M1 M1 A0	**ALLOW ECF** from (a) **<u>Examiner's Comments</u>** For this part of the question it was necessary for candidates to clearly show the substitution of the data into the equation. This includes the value of *g* (as 9.81 m s^{-2}) from the data sheet. It was also necessary for candidates to show that having determined v^2, this value needed to have the square root taken. Higher performing candidates wrote the final answer as 7.247 or 7.24685 ≈ 7.25 (m s^{-1}).
	c		u_h =22.3 sin 84 = 22.2 $v = \sqrt{22.2^2 + 7.25^2} = 23.35$ $(= \frac{1}{2} \times 0.210 \times 23.35^2) = 57.2$ (J) OR Change in potential energy = 0.210 ×9.81 ×2.40 = 4.94 Initial kinetic energy = $\frac{1}{2} \times 0.21 \times 22.3^2$ OR 52.2 (J) (4.94 + 52.2 =) 57.1 (J)	C1 C1 A1 C1 C1 A1	**ALLOW** v^2 = 545 **ALLOW** 57.2 (J) **<u>Examiner's Comments</u>** This question proved challenging to candidates. The common error was to calculate the kinetic energy using a value of 7.25 m s^{-1}. There were two main methods of answering this question: Either: determining the horizontal component of the velocity of the ball, (which remains constant) then working out the resultant velocity of the ball as it hits the ground and then calculate the kinetic energy. Or: Calculate the change in gravitational potential energy Calculate the initial kinetic energy of the ball And then add the two values together. **Misconception** Omitting the kinetic energy in the horizontal direction

					when calculating the kinetic energy of the ball. Candidates should be able to compare the motion of a projectile in two perpendicular directions and also confirm that similar results are obtained by considering energy transfers.
	d		(change of) Momentum = mass ×(change of) velocity As velocity increases, the momentum increases OR force = rate of change of momentum gravitational force acts on the ball and increases momentum OR Momentum is a vector quantity, change in direction means that the momentum changes.	M1 A1 M1 A1 M1 A1	**ALLOW** changes for increases **<u>Examiner's Comments</u>** There are many possible explanations as to why the momentum of the ball changes. To score full marks candidates needed to state a property of momentum, e.g. momentum = mass × velocity before then explaining why the momentum would change, e.g. as the ball falls, velocity increases so for constant mass the momentum increases.
			Total	**8**	
9	a		pV=nRT mass (or m) = nM Substitution into $\rho = \frac{m}{V}$ for m and V and cancelling n to give $\rho = \frac{pM}{RT}$	M1 M1 M1 A0	Not n=1 Not n=1 **<u>Examiner's Comments</u>** Successful candidates correctly identified the starting point for this question as the ideal gas equation, $pV = nRT$. Many candidates took the approach that n = 1 which was not sufficient. A more sufficient proof used the idea that the total mass of the gas was $n \times M$, allowing cancelling of the n in the ideal gas equation.
	b	i	$\rho = \frac{100\,000 \times 0.029}{8.31 \times 293}$ =1.19 kg m^{-3}	M1 A0	Accept R for 8.31, T = 293.1(5) Reject 20 for T. **<u>Examiner's Comments</u>** The vast majority of candidates correctly substituted values into the given formula, also remembering to convert the temperature from celsius into kelvin. Good practice for "show that" questions is to calculate the quantity required to at least one more significant figure in the question. In this example, that would mean evaluating the density to 1.19 kg m^{-3}.
		ii	Mass of air = 1.19 × 12,000 = 14 300 kg Weight of air = mg = 140 000 N	C1 A1	Accept all answers that round to 140 000 N, eg 140210, 141264

					Examiner's Comments In part (b) (ii), finding the weight was a matter of finding the mass and then finding the weight, all by using data in the question.
		iii	<u>Upthrust</u> = weight of fluid or air displaced Airship in equilibrium/resultant force is 0 (so upthrust = weight of the airship)	B1 B1	Do not accept unqualified “Archimedes' principle” Not water for fluid **Examiner's Comments** Part (b) (iii) required understanding of Archimedes' principle, rather than merely referring to it. Most candidates successfully related the principle to this context, writing about the upthrust being equal to the weight of fluid or air displaced by the gasbag. This is *always* true, regardless of the other forces that may be in play. References to displacement of water at this point were rejected. Fewer candidates completed the explanation by mentioning that the upthrust must be equal to the weight of the gas bag because we know that the gas bag is in equilibrium.
		iv	**Two** from • (Greater pressure) would increase the density/mass/weight of the helium • (increased pressure but) no change in volume therefore no more upthrust. • If the volume goes up then the upthrust will increase / ORA • Pressure only needs to be large enough to inflate the gasbag • (increased pressure difference or volume) may cause structural failure • (higher pressure means) more collisions of helium atoms with walls so more leakage of helium	B1 x 2	**Examiner's Comments** Most candidates scored a mark in part (b) (iv) because they referred to some sort of structural failure if the pressure increased. Others delved a bit deeper, correctly stating that an increase in mass without an increase in volume (and hence upthrust) would cause the gas bag to sink. **Misconception** Some candidates confused the ideas of mass and weight. Remember that weight = mass × gravitational field strength. **Misconception** Some candidates suggested that an increase in pressure alone would cause a change in temperature in this question, using the ideal gas equation as supporting evidence. Here, the pressure change has been caused by an increase in the number of moles of gas. As previously mentioned, candidates should take care to think about what is constant in such relationships and what is not.
	c		F = ([delta mass ÷ delta time] x speed =) 7.8 x 45	C1 A1	reject 'F=ma = 7.8 x 45' score zero annotate XP **Examiner's Comments**

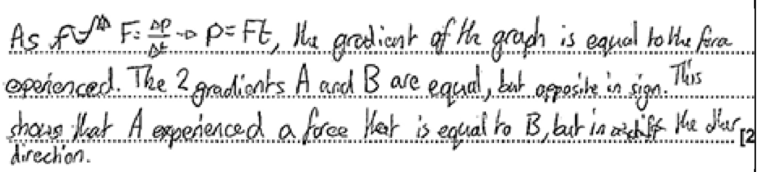
			= 350N		Question 20 parts (c) and (d) group well here. Part (c) is similar in nature to previous questions about rate of change of momentum. We rejected the use of the idea *F=ma* as it is wrong physics, even though the numerical value is the same.
	d		Density or mass per unit time is less so the (rate of) momentum change from the engines is reduced. There is less drag/resistive force on the airship.	B1 B1	**Examiner's Comments** The idea of rate of momentum transfer carries on in part (d). Most candidates correctly assumed that the density of air at high altitudes is much lower than at low altitudes. Many candidates implied that this meant a reduction in drag, which is correct. Far fewer correctly described the reduction of rate of change of momentum, causing less thrust. **Assessment for learning** Candidates should take care to use technical language. In this question, responses that included ideas of 'less air to push' or 'less mass moved per second' are insufficient at A2 Level.
			Total	**14**	
10			B	1	**Examiner's Comments** While virtually all candidates calculated the area of the trapezium correctly, candidates that forget that the time was measured in milliseconds picked answer D rather than the correct answer, B.
			Total	**1**	
11			C	1	**Examiner's Comments** A good number of candidates answered this correctly. As this collision is elastic, the total kinetic energy (KE) for the collision, ½ mu^2 remains unchanged. The total KE after the collision is ½ mv^2 + ½ mw^2. Equating these expressions gives statement 3 as correct, eliminating answers A and B. Statement 2 must also be correct and comes from conservation of momentum at right angles to the dashed line. Looking along the dashed line, the momentum is *mu* before the collision. After the collision, the component of momentum along the dashed line for P is $mv\cos\theta$. The angle Q makes with the dashed line is not θ, so the component of momentum along that dashed line for Q cannot be $mw\cos\theta$. This makes statement 1 false and so the correct answer is C.
			Total	**1**	

12			$\Delta p = (0.058 \times 7.2) - (0.058 \times -3.6)$ / 0.63 kg m s^{-1}/a = 208 ms^{-2} $F = \frac{0.63}{0.052}$ / F = 0.058 x 208 12(.05)(N)	C1 C1 A1	**ALLOW** 0.058x(7.2 − 3.6)/0.052 = 4.0N 1 mark **ALLOW** rounding to 12.1N 3sf from previous rounding in working **Examiner's Comments** Over half of candidates correctly selected the equations $F = \Delta p/\Delta t$ and $p = mv$ to calculate the average magnitude of the force but about a third of candidates did not understand vector notation and that the rebounding horizontal velocity 3.6 m s^{-1} was in the opposite direction to the incident horizontal velocity 7.2 m s^{-1}. As a result they calculated the change in momentum as 0.058 × (7.2 − 3.6) leading to an incorrect value for the average magnitude of the force of 4.0 N. **Misconception** This question demonstrated a common misconception to apply vector notation for the quantity of momentum. To correctly answer this question candidates needed to apply understanding that momentum is a vector and hence the change in momentum was 0.058 × (7.2 − (−3.6).
			Total	**3**	
13			A	1	**Examiner's Comments** Candidates performed less well on this question as they either interpreted that since the forces acting on the object in equilibrium were equal and opposite the object was at rest, or that the pair of forces were an interaction pair of forces, so B and C were the most common distractors.
			Total	**1**	
14	a	i	(area of shaded region =) 1.9 × 6.0 or 11.4 (m^2) (volume of air in 3.0 s =) 11.4 × 3.0 × 12 (mass of air = 11.4 × 3.0 × 12 × 1.2) mass of air = 492(.48) (kg)	C1 C1 A1	**Allow** volume found in one second leading to mass per second multiplied by 3 for 2nd and 3rd mark **Note**: volume of air is 410 (m^3)

		ii	Δp = 12 × 490 or 5900 (kg ms^{-1}) (force = Δp / Δt = 5900/3.0) F = 2000 (N)	C1 A1	Expect to see mass of 490, 492, 492.5, 492.48 **Note** answer is 1970 to 3 SF using 492.48 **Note** answer is 1960 to 3 SF using 490 **Examiner's Comments** Candidate's answers to this part were either jumbled or grounded in incorrect physics. This question is correctly answered by thinking about a cuboid of air that is 36 m long and has a cross-sectional area equal to that of the shaded side of the tent. That cuboid corresponds to the air that hits the tent in the three second period. The force applied will be equal to the rate of momentum change. This means multiplying the mass of air that hits the tent by the velocity change (i.e. 12 m/s) and then dividing by the time taken for that momentum change.
	b		***Level 3 (5–6 marks)** Clear descriptions **and** explanations, supported by quantitative analysis *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.* **Level 2 (3–4 marks)** Some description and some explanation or quantitative analysis **or** Clear explanation **or** Clear description **or** Clear quantitative analysis *There is a line of reasoning presented with some structure. The information presented is in the most part relevant and supported by some evidence.*	B1×6	**Indicative scientific points may include**: **Description** • Increasing the area/diameter of the guy ropes • A different material with a larger breaking or yield stress • A more streamlined shape that allows the wind to pass over or around the tent **Explanation** • Correct reference/use of $F = \Delta p / \Delta t$ • Greater cross-sectional area of rope would reduce the stress • The rope would not exceed a higher breaking/yield stress • Changing shape produces a smaller momentum change and a smaller force • If the air passes over/around the tent, it still has some forward momentum and hence the change and force is less • Reduction of angle of ropes from ground reduces component of tension perpendicular to ground so tension decreases. **Quantitative analysis**

			Level 1 (1–2 marks) Limited description **or** Limited explanation *There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.* **0 marks** *No response or no response worthy of credit.*		• Mass (per unit time) and velocity **both** double (at 40 m/s) • Momentum change is ×4 • Force would increase by a factor of 4 • Rope cross section must be × 4 (or diameter × 2) • Breaking or yield stress of material would need to be × 4 • Use of trigonometry to determine the angle of deflection that would reduce the momentum change by a factor of 4 (about 15° compared to the original 90°) **<u>Examiner's Comments</u>** This question tested ideas about forces, resolution of forces, behaviour of materials under stress and rate of change of momentum transfer. Level 1 answers were restricted to merely suggestions of what could be done to make the support of the tent stronger. Level 2 answers developed at least one of those suggestions by referring, qualitatively, to the underlying physics. Level 3 answers were rare, as the requirement was for some quantitative physics. Candidates that attempted a quantitative answer often believed that the force would be doubled, when in fact it is quadrupled. This is because both the mass of the air depends on the velocity of air, so doubling the speed will also double the mass, thus quadrupling the momentum transfer.  This candidate clearly states, on lines 3–5, that the force is directly proportional to the square of the speed by thinking about their answers to previous parts of the question. The statements following this, after the page break, are sensible and grounded in physics in topics typically covered in the first year of study. The candidate mentions about quadrupling the number of ropes and reducing the

					area presented to the wind by a factor of four. The candidate goes on, in the additional answer space, to refer to the thickness of the ropes and how the radius would need to double. Level 3 response.
			Total	**11**	
15			**A**	1	
			Total	**1**	
16			**C**	1	**<u>Examiner's Comments</u>** The first step with this question is to calculate the resultant force, which is 0.2 N upwards (eliminating option A). As the drag force is upwards, the direction of motion must be downwards (eliminating option D). Since the resultant is opposite to the direction of travel, this object must be decelerating.
			Total	**1**	
17			**A**	1	**<u>Examiner's Comments</u>** Candidates found this question challenging. Conservation of momentum applies both horizontally and vertically here. This means that the vertical upwards component of the momentum of X must equal the vertical downwards component of the momentum of Y. So $mv_1 \sin(60°) = 4m\, v_2 \sin(30°)$. Rearranging this expression will give the correct answer of v_1 / v_2.
			Total	**1**	
18			**C**	1	**<u>Examiner's Comments</u>** Most candidates suggested that angular frequency and angular velocity do not have the same or equivalent units. The correct answer is C, because gravitational potential is measured in J kg^{-1} and kinetic energy is measured in J.
			Total	**1**	

19	a		Gradients/rate of change of momentum are opposite/ positive & negative Gradients/rate of change of momentum of the graphs have the same magnitude/Force on A and B = 24000N	B1 B1	**Ignore** change in momentum is the same for **A** and **B** **Allow** calculations of the gradient for 2 marks **A** F = (20 – (−4))/1ms = 24000N and **B** F = (−30 – 6)/1ms = −24000N **Ignore POT** **Allow** 1 mark if no reference to the graph - The forces acting on each object are opposite and the (magnitude) of the forces are the same **<u>Examiner's Comments</u>** Candidates performed less well on this question as half of candidates were not given any marks. To access both marks candidates had to refer to the graph but very few candidates applied their knowledge of Newton's Laws to determine that the gradient of the graph represented the force acting on objects A and B during the collision. Some candidates referred to the graph but only in terms of the change in momentum with no reference to time. If candidates made no reference to the graph, they could access 1 mark for giving a correct definition of Newton's 3rd Law for the two objects but quite often the definition was vague and incomplete (see misconceptions) so no marks were given. Exemplar 1  As F = Δp/Δt → p = Ft, the gradient of the graph is equal to the force experienced. The 2 gradients A and B are equal, but opposite in sign. This shows that A experienced a force that is equal to B, but in the other direction. [2 This response demonstrates a clear understanding of Newton's 3rd Law and that the force acting during the collision is the gradient of the graph. This exemplar demonstrates a middle range and higher end response from candidates. ? **Misconception** The most common definition for Newton's 3rd Law was 'every action has an equal and opposite reaction. '
	b		momentum before = 20 – 30 (= −10 kg m s^{-1}) momentum after = −4 −6 (= −10 kg m s^{-1}) (Therefore, the momentum is conserved)	B1 B1	**Allow** alternative answer of: loss of momentum of A = 24 (kg/m/s) gain of momentum by B = 24 (kg/m/s) (Therefore, the momentum is conserved) **<u>Examiner's Comments</u>** Most candidates performed well on this question as they used the graph to show that the total momentum before and after the collision for objects A and B was conserved

					and that the values were the same. If marks were not given it was generally because candidates had not followed on with and carried out a simple calculation even though they had read the correct momentum values from the graph.
	c		$(2.0 + 3.0)\ v = 10$ $v = 2.0$ (m s^{-1})	C1 A1	**Allow** answer of 2 **1sf**, without any **SF** penalty **Ignore** sign **<u>Examiner's Comments</u>** About half of candidates were given 2 marks for correctly calculating the velocity of objects A and B combined after the collision. Most candidates used an expression for the momentum of the combined objects (5*v*) and equated this to the total momentum of the two objects before the collision (10 kg m s^{-1}). A significant number of candidates did not apply the conservation of momentum correctly and used a momentum value from the graph or didn't use the combined mass of the objects A and B.
	d		$s = ½\ gt^2$ $120 = ½ × 9.81 × t^2$ $t = 4.9$ (s)	C1 C1 A1	**Allow** 4.95, **not** 5.0 **<u>Examiner's Comments</u>** Candidates at the higher end performed better on this question as they were able to identify and apply the correct equation of motion and determine that the initial vertical component of the velocity was zero. Candidates at the lower end tended to either omit the question or make an incorrect attempt to use an equation of motion using a value for the initial velocity (usually the velocity calculated from part c). **Misconception** Candidates did not realise that horizontal and vertical motion are independent to each other and hence that the initial vertical component of velocity for the falling objects was zero.
			Total	**9**	