Name: _____

Momentum

Date:

Time:

Total marks available:

Total marks achieved: _____

Mark Scheme

Q1.

	Answer	Acceptable answers	Mark
	A 600 kg m/s		**(1)**

Q2.

	substitution: 0.5 × 18 (1) evaluation 9.0 (1)	 9 give full marks for correct answer no working	**(2)**

Q3.

	Answer	Acceptable answers	Mark
(i)	shown using data Any two from kinetic energy before = 12.5 + 0 (=12.5) (1) kinetic energy after = 4.5 + 8 (=12.5) (1) Kinetic energy is the same before and after the collision (1)	 Kinetic energy is conserved/no energy lost	**(2)**
(ii)	cyclotron (1)	named particle accelerator accept CERN	**(1)**

Q4.

	Answer	Acceptable answers	Mark
(i)	horizontal arrow (judge by eye), pointing to the right **anywhere**on the		

	diagram 		**(1)**
(ii)	substitution: (1) 130 000 × 75 evaluation: (1) 9 750 000 (kgm/s) (Ns)	give full marks for correct answer, no working Ignore minus sign 9.75 x 10^6 (kgm/s) (Ns)	**(2)**
(iii)	9 750 000 kgm/s	same value as answer to (b)(ii) Ignore minus sign	**(1)**

Q5.

	Answer	**Acceptable answers**	**Mark**
(i)	An explanation linking two of the following: • force is smaller/less (1) • momentum changes more slowly (1) • lower deceleration (1) • use of the formula (1)	 pressure is smaller/less slower deceleration force is proportional to rate of change of momentum/F= (mv – mu)/t	**(2)**
(ii)	Any two from: (for loaded aircraft) • has more mass (1) • has more momentum (1) • has more k.e. (1) • higher velocity • brakes need to do more work (1)	accept reverse argument for empty aircraft heavier/more passengers/more cargo higher speed/moving faster	**(2)** **expert**

Q6.

Question Number	Answer	Mark
*	Answers will be credited according to candidate's deployment of knowledge and understanding of the material in relation to the qualities and skills outlined in the generic mark scheme. The indicative content below is not prescriptive and candidates are not required to include all the material which is indicated as relevant. Additional content included in the response must be scientific and relevant. **AO1 (6 marks)** • momentum = mass × velocity • action and reaction are equal and opposite (N 3) • force of R on Q = -force of Q on R • $\frac{\text{change in momentum of Q}}{\text{time}} = -\frac{\text{change in momentum of R}}{\text{time}}$ • time of collision same for both • change in momentum of Q = - change in momentum of R • no overall change in momentum • R accelerates because of force from Q • transfer of momentum between Q and R	**(6)** AO 1 1

Level	Mark	Descriptor
	0	• No rewardable material.
Level 1	1-2	• An explanation that demonstrates elements of physics understanding, some of which is inaccurate. Understanding of scientific ideas lacks detail. (AO1) Presents an explanation with some structure and coherence. (AO1)
Level 2	3-4	• An explanation that demonstrates physics understanding, which is mostly relevant but may include some inaccuracies. Understanding of scientific ideas is not fully detailed and/or developed. (AO1) • Presents an explanation that has a structure which is mostly clear, coherent and logical. (AO1)
Level 3	5-6	• An explanation that demonstrates accurate and relevant physics understanding throughout. Understanding of the scientific ideas is detailed and fully developed. (AO1) • Presents an explanation that has a well-developed structure which is clear, coherent and logical. (AO1)

Q7.

	Answer	Acceptable answers	Mark

(i)	substitution (1) 67 × 31 evaluation (1) 2077 (kg m/s)	 2080, 2100 working backwards using 2000 (v=) 29.85, 30 (m=) 64.52, 65 67 X 31=2000 scores only one mark	**(2)**
(ii)	substitution (1) 2000 ÷ 2.3 evaluation (1) 870 (N)	answer to (b)(i)) ÷ 2.3 900, 869.6, 869.5 903	**(2)**
(iii)	an explanation linking two of the following • Force on Andrew is quite small (1) • Because impact time is long (1) • The acceleration/deceleration is quite small (1) • Because impact distance is far (1)	force is reduced/ less /not as strong slows down/changes momentum gradually acceleration = 1.35 'g' or 13.5 m/s^2 slows down (rate of) change of momentum scores 2 marks	**(2)**

Q8.

	Answer	**Acceptable answers**	**Mark**
(i)	momentum = 0.03 × 170 (1)	Accept 5.1 seen	**(1)**
(ii)	momentum before = momentum after (1) 5.1 = 0.83 × v (1) v = 6.1 (m/s) (1)	allow 5.0 = 0.80 x v for 1 mark max 5.0 = 0.83 × v v = 6.0 (m/s) allow ecf from (a)(i) give full marks for correct answer, no working	**(3)**
(iii)	Statement to include any two from • kinetic energy is not conserved (1) • (lost ke) appears as heat/sound (1) • momentum is conserved (1)	 ke not conserved / some ke lost no momentum lost	**(2)**

Q9.

		Indicative Content	
QWC	*	An explanation including some of the following ideas • brakes apply a force to the car • this force from brakes makes the car decelera velocity • a force also acts on the driver • driver decelerates at same rate as the car • does not move with respect to car/ stays in the • moves slightly because belt stretches • small/ no horizontal force acts on the shopping • shopping bag continues at similar/ same veloc • until shopping bag falls off seat / hits dashboa • ideas can be expressed in terms of energy, mo and/or by reference to Newton's laws	
Level	**0**	No rewardable content	
1	**1 - 2**	• A limited explanation of the difference in decelerations of at least two of the objects Car **(C)**, Shopping **(S)**and Passenger **(P)**mainly describing the effects. E.g. (at start) **C**stops (very quickly) while {**P / S**} carries on moving (for a longer time) OR **S**{carries on at same speed / hits the dashboard} while **P**is {held back / slowed down} (by the seatbelt) • the answer communicates ideas using simple language and uses limited scientific terminology • spelling, punctuation and grammar are used with limited accuracy	
2	**3 - 4**	• A simple explanation of the difference in decelerations of at least **two**of the objects Car, Shopping and Passenger, including a reason for at least one of the decelerations. E.g.(at start) **C**stops (very quickly) **because of**friction at the brakes and at the road while {**P / S**} carries on moving (for a longer time) OR **S**{carries on moving (at same speed) / hits the dashboard} while **P**is {held back / slowed down} **because of**stretching force from the seatbelt) • the answer communicates ideas showing some evidence of clarity	

		and organisation and uses scientific terminology appropriately • spelling, punctuation and grammar are used with some accuracy	
3	**5 - 6**	• A detailed explanation of the relative decelerations of **C**, **S and P**including mention of the physical principles involved in any two such as that named forces are needed to change given motions. E.g. (The force of) friction is large for **C**to {slow down / stop} quickly but is low for **P**and **S**. {**So / thus / therefore etc**} **P**or **S**carry on at the same speed (initially). **P**decelerates more slowly than **C**{**because / as a result etc**} of the stretching (force) of the seatbelt. OR *The idea of {*Newton's first law / inertia / need for a force to change motion} and the role of friction and {elastic / tension / stretching} force in producing the **three**named decelerations. OR Named force needed for a described change in {momentum/kinetic energy} to {stop / slow down} each of the **three**objects. • the answer communicates ideas clearly and coherently uses a range of scientific terminology accurately • spelling, punctuation and grammar are used with few errors	

Q10.

	Answer	**Acceptable answers**	**Mark**
(a)(i)	momentum = 0.03 × 170 (1)	Accept 5.1 seen	**(1)**
(a)(ii)	momentum before = momentum after (1) 5.1 = 0.83 × v (1) v = 6.1 (m/s) (1)	allow 5.0 = 0.80 x v for 1 mark max 5.0 = 0.83 × v v = 6.0 (m/s) allow ecf from (a)(i) give full marks for correct answer, no working	**(3)**
(a)(iii)	Statement to include any two from • kinetic energy is not conserved (1) • (lost ke) appears as heat/sound (1) • momentum is conserved (1)	 ke not conserved / some ke lost no momentum lost	**(2)**
(b)(i)	an explanation linking • momentum (must be) conserved (1) • so must have positive and negative momentum (1)	 photons move in opposite directions indication of movement in opposite directions (e.g. opposite velocities)	**(2)**

(d)(ii)	$E = (2 \times) 9.1 \times 10^{-31} \times [3 \times 10^{8}]^{2}$ (1) $= 1.6 \times 10^{-13}$ (J) (1)	8.2×10^{-14} (0.82×10^{-13}) for 1 mark give full marks for correct answer, no working	**(2)**

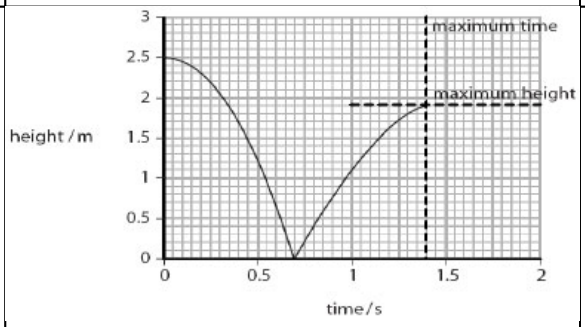
Q11.

	Answer	**Acceptable answers**	**Mark**
(a)	Description including 3 of the following: • (Gravitational) potential energy (transferred) to KE(1) • Idea of energy transfer to heat/sound whilst descending (1) • Chemical energy is transferred to heat energy in Andrew (1) • Idea of energy dissipated on stopping (1)	(G)PE (transferred) to KE Allow gravitational energy for GPE Energy transferred to heat because of air resistance/ friction The energy goes to heat as he stops. Energy is transferred to the surroundings	**(3)**
(b)(i)	substitution (1) 67 × 31 evaluation (1) 2077 (kg m/s)	2080, 2100 working backwards using 2000 (v=) 29.85, 30 (m=) 64.52, 65 67 X 31=2000 scores only one mark	**(2)**
(b)(ii)	substitution (1) 2000 ÷ 2.3 evaluation (1) 870 (N)	answer to (b)(i)) ÷ 2.3 900, 869.6, 869.5 903	**(2)**
(b)(iii)	an explanation linking two of the following • Force on Andrew is quite small (1) • Because impact time is long (1) • The acceleration/deceleration is quite small (1)	force is reduced/ less /not as strong slows down/changes momentum gradually acceleration = 1.35 'g' or 13.5 m/s^2 slows down (rate of) change of momentum scores 2 marks	**(2)**

	• Because impact distance is far (1)		

Total question = 8 marks

Q12.

	Answer	Acceptable answers	Mark
(a)(i)	2.5 (m)	Allow answers between (and including) 2.45 & 2.55	**(1)**
(a)(ii)	0.7 (s)	Allow answers between (and including) 0.68 & 0.72	**(1)**
(a)(iii)	 line: same shape as original (1) peak at 1.9 m (1) time taken < 0.7 s (1)	Ignore any part of the graph after the peak	**(3)**
(a)(iv)	An explanation linking: energy lost (1) in collision with ground / air resistance (1)	Inelastic collision worth (2) as sound or heat	**(2)**
(b)(i)	shown using data Any two from kinetic energy before = 12.5 + 0 (=12.5) (1) kinetic energy after = 4.5 + 8 (=12.5) (1) Kinetic energy is the same before and after the collision (1)	Kinetic energy is conserved/no energy lost	**(2)**
(b)(ii)	cyclotron (1)	named particle accelerator accept CERN	**(1)**

Q13.

	Answer	Acceptable answers	Mark
(a)	kinetic (energy)	Movement (energy) KE	**(1)**
(b)	substitution: 0.6 × 20 (1) evaluation 12 (1) J (1)	 give 2 marks for correct answer no working unit is an independent mark joules, Nm, kgm^2/s^2 , Ws	**(3)**
(c)	substitution: 0.5 × 18 (1) evaluation 9.0 (1)	 9 give full marks for correct answer no working	**(2)**

		Indicative Content	
QWC	***(d)**	a description including some of the following points: • chemical to kinetic while in his hand • kinetic (gradually) to potential while rising / fr • eventually all potential at 10 m with a little the energy • some mention of conservation of energy • potential (gradually) to kinetic as falls / 10 m-0 • with a little more thermal (heat) energy • at 0 m sound energy • at 0 m thermal (heat) energy	
Level	**0**	No rewardable content	
1	**1 - 2**	• a limited description which identifies a change in one relevant type energy or a transfer of energy from one form to another e.g. kinetic energy increases OR kinetic energy changes to sound. • the answer communicates ideas using simple language and uses limited scientific terminology • spelling, punctuation and grammar are used with limited accuracy	
2	**3 - 4**	• a simple description giving detail of a relevant energy change/transfer e.g. kinetic energy changes into potential energy as it moves upwards OR kinetic energy increases as it falls. • the answer communicates ideas showing some evidence of clarity and organisation and uses scientific terminology appropriately • spelling, punctuation and grammar are used with some accuracy	
3	**5 - 6**	• a detailed description of a sequence of relevant energy changes	

		/transfers e.g. kinetic energy is transferred into potential energy as it rises. This then changes back into kinetic energy as it falls back down. • the answer communicates ideas clearly and coherently uses a range of scientific terminology accurately • spelling, punctuation and grammar are used with few errors	

Q14.

	Answer	**Acceptable answers**	**Mark**
(a)(i)	B it decreases		**(1)**
(a)(ii)	C it does not change		**(1)**
(b)(i)	horizontal arrow (judge by eye), pointing to the right **anywhere**on the diagram 		**(1)**
(b)(ii)	substitution: (1) 130 000 × 75 evaluation: (1) 9 750 000 (kgm/s) (Ns)	give full marks for correct answer, no working Ignore minus sign 9.75×10^6 (kgm/s) (Ns)	**(2)**
(b)(iii)	9 750 000 kgm/s	same value as answer to (b)(ii) Ignore minus sign	**(1)**
(c)(i)	An explanation linking two of the following: • force is smaller/less (1) • momentum changes more slowly (1) • lower deceleration (1) • use of the formula (1)	pressure is smaller/less slower deceleration force is proportional to rate of change of momentum/F= (mv – mu)/t	**(2)**
(c)(ii)	Any two from: (for loaded aircraft) • has more mass (1) • has more momentum (1) • has more k.e. (1) • higher velocity • brakes need to do more work (1)	accept reverse argument for empty aircraft heavier/more passengers/more cargo higher speed/moving faster	**(2) expert**

Total marks for question = 10 marks

Q15.

Question Number	Answer	Acceptable answers	Mark
(a)(i)	Circular/spiral/circle		**(1)**

Question Number	Answer	Acceptable answers	Mark
(a)(ii)	An explanation linking three of the following. • (fast moving) <u>protons</u> (1) • absorbed by (1) • nuclei (1) • (produces)unstable nuclei (1)	bombard / hit /strike / collide with stable atoms / stable element	**(3)**

Question Number	Answer	Acceptable answers	Mark
(b)(i)	B momentum		**(1)**

Question Number	Answer	Acceptable answers	Mark
(b)(ii)	(Momentum/it)equals mass x <u>velocity</u>	p = m x v kilograms / kg is the mass and metres per second / m/s is the <u>velocity</u> Accept "times" for x	**(1)**

Question Number		Indicative Content	Mark
QWC	*** (b) (iii)**	An explanation including some of the following points Diagram 1 • Moving in opposite directions before collision • inelastic collision • stationary after collision • momentum zero after collision • (therefore) total momentum must have been zero before collision • (therefore) cars were moving at the same speed in opposite directions (assuming cars have equal mass) • both cars had kinetic energy before the collision • KE zero after collision • KE converted into heat, sound, elastic potential energy etc. Diagram 2 • Elastic collision / almost elastic collision • Momentum conserved • Momentum transferred from first to last sphere • KE conserved / almost conserved • (because)last sphere reaches same height as first sphere • Three spheres always have zero momentum • Small amount of energy transferred to sound/heat	**(6)**

Level	**0**	No rewardable content
1	**1 - 2**	• A limited analysis of ONE collision which is given by a correct statement e.g. In collision 1, kinetic energy has been lost OR In collision 2 momentum is transferred from the first to the last sphere. • the answer communicates ideas using simple language and uses limited scientific terminology • spelling, punctuation and grammar are used with limited accuracy
2	**3 - 4**	• a simple analysis of BOTH collisions considering BOTH momentum AND kinetic energy correctly for each one e.g. In collision 1, momentum is conserved and the kinetic energy of the cars changes. In collision 2, momentum and the kinetic energy is conserved. • answer communicates ideas showing some evidence of clarity and organisation and uses scientific terminology appropriately • spelling, punctuation and grammar are used with some accuracy
3	**5 - 6**	• a detailed analysis of BOTH collisions considering momentum AND kinetic energy for each collision correctly for each AND detailed reference to EITHER diagram. e.g. In collision 1, the momentum before and after the collision is zero because momentum is always conserved, but the KE is lost. In collision 2, all the momentum and KE is transferred to the last sphere because it gets to the same height as the first one. • the answer communicates ideas clearly and coherently uses a range of scientific terminology accurately • spelling, punctuation and grammar are used with few errors

(Total marks for question = 12 marks)

Q16.

Question Number	Answer	Acceptable answers	Mark
(a)(i)	**A**		**(1)**

Question Number	Answer	Acceptable answers	Mark
(a)(ii)	A description to include any two of • Gravitational / potential energy reduces (1) • kinetic energy increases (1) • total energy remains constant (1)	Ignore energy changes resulting from impact with sand GPE reduces KE increases Allow GPE is transferred to KE for 2 mark	**(2)**

Question Number	Answer	Acceptable answers	Mark
(b)	A explanation linking • (work is done) displacing the sand (1) with EITHER • (as) kinetic energy of the ball(s) has been transferred (1) OR • by the force between the ball and the sand (1)	sand moving/ pushing/ blowing upwards OWTTE or ball sinking into sand	**(2)**

Question Number	Answer	Acceptable answers	Mark
(c) (i)	transposition mass = momentum / velocity (1) substitution mass = 0.46 / 6.2 (1) evaluation 0.074 (kg) / 74g (1)	Subst. and transform. either order 1 mark only can be scored for correct substitution after incorrect transposition. Give full marks for correct answer with no working. Answers that round to 0.074 (kg) 0.07 (kg)	**(3)**

Question Number	Answer	Acceptable answers	Mark
(c)(ii)	substitution (impact) force = 0.46 / 0.17 (1) evaluation 2.7 (N) (1)	Give full marks for correct answer with no working. Ignore power of ten error until evaluation Answers which round to 2.7 Allow ECF if candidate has used mass from part (i) in F=m(v-u) / T F= $\frac{6.2 - 0}{0.17}$ X 0.074 (1) = 2.7 (N) (1)	**(2)**

Q17.

	Answer	**Acceptable answers**	**Mark**
(a) (i)	D the same size as the driving force		**(1)**
(a) (ii)	transposition: (1) (change in) speed= acceleration × time substitution: (1) speed = 12 × 4 evaluation: (1) 48 (m/s) (1)	transposition and substitution can be in either order substitution mark can be scored when incorrectly transposed word/symbol equation is given Give full marks for correct answer no working	**(3)**
(b)	An explanation linking	Attempt to use f = m × a scores	**(2)**

	• {acceleration of sports is 2x / time to reach 30 m/s is ½} that of family car / RA (1) • mass of sports car LESS than ½ that of family car or RA (1) (so resultant force required is less)	one mark e.g. 4200 OR 3600 scores 1 Correct numerical comparison scores both marks e.g. 4200:3600 numerically or in words scores 2 marks	

		Indicative Content	
QWC	***(c)**	An explanation including some of the following ideas • brakes apply a force to the car • this force from brakes makes the car decelera velocity • a force also acts on the driver • driver decelerates at same rate as the car • does not move with respect to car/ stays in the • moves slightly because belt stretches • small/ no horizontal force acts on the shopping • shopping bag continues at similar/ same veloc • until shopping bag falls off seat / hits dashboa • ideas can be expressed in terms of energy, mo and/or by reference to Newton's laws	

Level	**0**	No rewardable content
1	**1 - 2**	• A limited explanation of the difference in decelerations of at least two of the objects Car **(C)**, Shopping **(S)**and Passenger **(P)**mainly describing the effects. E.g. (at start) **C**stops (very quickly) while {**P / S**} carries on moving (for a longer time) OR **S**{carries on at same speed / hits the dashboard} while **P**is {held back / slowed down} (by the seatbelt) • the answer communicates ideas using simple language and uses limited scientific terminology • spelling, punctuation and grammar are used with limited accuracy
2	**3 - 4**	• A simple explanation of the difference in decelerations of at least **two**of the objects Car, Shopping and Passenger, including a reason for at least one of the decelerations. E.g.(at start) **C**stops (very quickly) **because of**friction at the brakes and at the road while {**P / S**} carries on moving (for a longer time) OR **S**{carries on moving (at same speed) / hits the dashboard} while

		Pis {held back / slowed down}**because of**stretching force from the seatbelt) • the answer communicates ideas showing some evidence of clarity and organisation and uses scientific terminology appropriately • spelling, punctuation and grammar are used with some accuracy	
3	**5 - 6**	• A detailed explanation of the relative decelerations of **C**, **S and P**including mention of the physical principles involved in any two such as that named forces are needed to change given motions. E.g. (The force of) friction is large for **C**to {slow down / stop} quickly but is low for **P**and **S**. {**So / thus / therefore etc**}**P**or **S**carry on at the same speed (initially). **P**decelerates more slowly than **C**{**because / as a result etc**} of the stretching (force) of the seatbelt. OR *The idea of* {Newton's first law / inertia / need for a force to change motion} and the role of friction and {elastic / tension / stretching} force in producing the **three**named decelerations. OR Named force needed for a described change in {momentum/kinetic energy} to {stop / slow down} each of the **three**objects. • the answer communicates ideas clearly and coherently uses a range of scientific terminology accurately • spelling, punctuation and grammar are used with few errors	