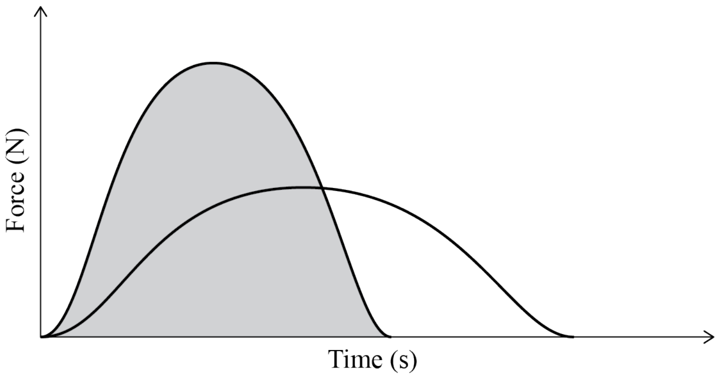
Level 2 Physics: Mechanics – Newton's Laws, Momentum and Energy Answers

Question	Evidence	Achievement	Merit	Excellence
2020(2) (d)	$\Delta p = F\Delta t$ $\Delta p = p_f - p_i$ $= 0 - 12 \times 1600 = -19\,200$ $F_{\text{crumple}} = \frac{19\,200}{0.8} = 24\,000\ N$ Without crumple zone: $F_{\text{no crumple}} = \frac{19200}{0.2} = 96\,000\ N$ So crumple zone collapses and increases time for collision, and the force from the seatbelts on the occupants is reduced (only ¼ as much).	Correct momentum change. OR ONE correct force. OR Explanation of crumple zone.	BOTH correct forces.	Correct values AND Justify how crumple zone works, including statement that Δ*p* is the same in both situations.
2019(3) (a)	There is a force from the stick to the ball, and an equal and opposite force from the ball to the stick	Correct statement of Newton's third law.		

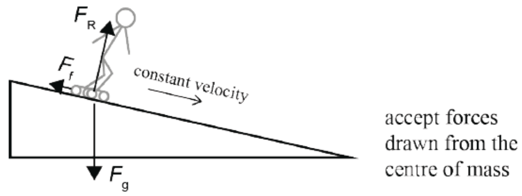
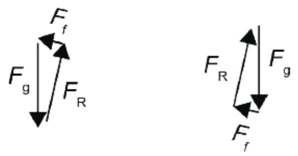
(b)	Assumption is conservation of momentum/no external forces $p_{before} = p_{after}$ Initial momentum of ball = 0, so initial momentum is that of stick. $p_{initial} = 0.6 \times \overrightarrow{18} = \overrightarrow{10.8}$ $p_{final} = 0.6 \times \overrightarrow{12} + 0.16 v_{ball}$ $v_{ball} = \overrightarrow{22.5} \text{ m s}^{-1}$	Correct assumption OR Total initial momentum	Correct assumption AND Correct final velocity.	
(c)	$\Delta p = m\Delta v = 0.16 \times 40 = 6.40 \text{ kg m s}^{-1}$ $F = \frac{\Delta p}{t} = \frac{6.4}{0.02} = 320 \text{ N}$ Allow approach using acceleration.	Correctly calculates Δp OR calculates F by calculating *F* = *ma* Uses incorrect value for Δv of 20 m s^{-1} giving an incorrect *F* of 160 N.	Uses impulse to calculate *F* correctly.	

(d)(i) (ii)	 Second graph has smaller peak force and spread over significantly longer time Identifies the cushioning effect of the pads to increase the time for collision and reduce the force. Because the change of momentum/impulse is the same. Identifies less force will cause less damage and reduce the risk of injury (A only). Explains the absorption of energy by the pads and the increase on time effect on the collision (A only).	Second line correctly drawn – areas under graphs must be approximately comparable. (Accept line not starting at t = 0 as long as it follows other criteria.) OR One other bullet point.	TWO points.	Comprehensive discussion, including correct graph line. Discussion must include more time/less force and same Δp.

2018(2) (c)	$\Delta p = F\Delta t = 20.0 \times 0.140 = 2.80$ kg m s^{-1} (SHOW Q) $\Delta p = p_f - p_i = m_{\text{balloon}}\, v_{\text{balloon final}} - (m_{\text{balloon}} \times 0)$ $2.80 = 0.180 v_{\text{balloon}} - 0$ $v_{\text{balloon}} = 15.6$ m s^{-1}	Correct working to show change in momentum but *v* wrong OR Correct *v* without showing working for Δp	All correct with complete working.	

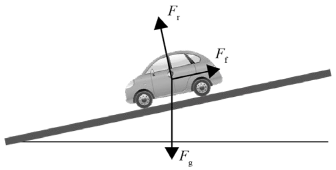
(d)	Point A Impulse argument: For Jimmy to reduce the force the balloon experiences, he needs to increase the collision time. Because the Δ*p* is fixed ($p_f = 0$) as balloon stops and $p_i = mv$ and the mass and initial velocity remain unchanged, a longer collision time will reduce the force according to $F = \Delta p/\Delta t$ (reducing the chance of the balloon bursting). OR: Similar argument using $F = ma$: For Jimmy to reduce the force the balloon experiences, he needs to reduce the acceleration ($F = ma$) by increasing the collision time ($a = \Delta v/\Delta t$) because Δv is fixed. (a lower force reduces the chance of the balloon bursting). OR Similar argument using $W = Fd$: For Jimmy to reduce the force the balloon experiences, he needs to increase the distance taken for the balloon to stop. The work done ($\Delta E = E_{k\ final} - E_{k\ initial}$) is fixed, so a longer stopping distance causes a lower force, (that reduces the chance of the balloon bursting).	Point A OR ONE of: reduce force; increase collision time; increase collision distance; reduce acceleration	Point A AND logical argument with an omission or no appropriate formula etc. OR: Only (d)(ii) correct.	(d)(i) correct AND: Linked argument including an appropriate formula or statement about initial and final speed or kinetic energy or momentum, linked to reduction of force.

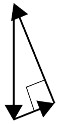
2017(1) (a)	Total momentum of the system is conserved, assumption, no external forces.	Correct answer with correct assumption.		
(b)	$p_i = m_{Katy} v_{Katy} + m_{Aroha} v_{Aroha}$ $p_i = (65 \times 8.5) + (50 \times 6.0) = 552.5 + 300 = 852.5 = 850$ Kg m s^{-1} $p_i = p_f = v_{combined} \times (m_{Katy} + m_{Aroha})$ $852.5 = v_{combined} \times (65 + 50)$ $v_{combined} = 7.4$ m s^{-1}	Correct formulae and correct substitution for total initial p and total final p. OR $p_{initial} = 853$ kg m s^{-1}	Correct velocity.	
(c)	Solved using impulse: $\Delta P = P_f - P_i$ $\Delta P = (50 \times 7.4) - (50 \times 6)$ $\Delta P = 370 - 300$ $\Delta P = 70$ kg m s^{-1} $F = \frac{\Delta P}{\Delta t}$ $F = \frac{70}{2.5}$ $F = 28$ N Solved using Newton's second law: $\Delta v = v_f - v_i = 7.4 - 6.0 = 1.4$ m s^{-1} $a = \frac{\Delta v}{\Delta t} = \frac{1.4}{2.5} = 0.56$ m s^{-1} $F = ma = 50 \times 0.56 = 28$ N	Correct value of Δp or a calculated. OR Incorrect value of Δp, but consequently correct answer for force.	Correct value of force AND Correct change in momentum OR acceleration.	

(d)(i) (ii)	  Possible force labels include: reaction/support/normal force weight/gravity/force.	2 forces labelled correctly, and in correct directions. Ignore size of the forces.	For part (i), all forces labelled correctly, and in correct directions. Ignore size of the forces. A closed vector diagram drawn with one error.	All forces labelled correctly, and in correct directions in part (i). AND Correct diagrams, with correct labels and approximately correct sizes and directions. F_g must be vertically downwards.

2017(2) (d)	The total momentum of the jumper has to become zero after landing, and Δ*P* will be the same for all jumps. So, the force will depend on the duration of the compression. Springs can be made of a softer material, which decrease the spring constant. Springs will be compressed more, and it will take longer time to be compressed. Springs can be made longer in length (thicker mattress), so the spring constant decreases, and it takes longer time to compress the springs. Longer time means less force on the jumper, as the impulse will be the same. Any other correct suggestions.	One valid change in the design suggested.	One valid change is suggested with a correct explanation.	Two changes are suggested with full correct explanation.
2016(1) (b)	$m_r v_r + m_b v_b$ before = $m_r v_r + m_b v_b$ after $(0.050 \times 1.5) + 0 = (0.040 \times 1.2) + (0.05 \times v)$ $v = 0.54 \text{ m s}^{-1}$	Correct equation and correct substitution.	Correct answer.	
(c)	$\Delta p = 0.04 \times 1.2 = 0.048$ OR $\Delta p = 0.05 \times (1.5 - 0.54) = 0.048$ $\Delta p = F \times t$ $0.048 = F \times 0.08$ $F = 0.60$ N	Change in momentum calculated for either car. OR Acceleration calculated for either car if $F = ma$ used.	Correct answer.	

2015(2) (a)(i)	Either conservation of momentum or Newton's first, second or third law. (Cannot be conservation of energy.)	One correct law.		
(ii)	Momentum is conserved. $5.0m = (65 + m)2.2$ $5.0m - 2.2m = 143$ $m = 51$ kg	Recognition that momentum is conserved. OR Correct expression for p_{before} or p_{after} OR states $\Delta p = 143$	Correct answer for mass. AND Correct assumption.	
(iii)	Momentum was conserved in the absence of external force. There is no friction with ice. Friction is an external force.	States that momentum is conserved in the absence of an external force. OR Recognition of the absence of external force since ice is frictionless.	Reasons out that friction is an external force, and this is zero due to the presence of ice, in order for momentum to be conserved.	

(b)	Janet must bend her knees while jumping to the ground. Bending her knees increases her stopping time so the force decreases. This is because the change in momentum remains the same. $\Delta p = F\Delta t$ Accept correct argument in terms of $F = ma$.	Janet needs to bend her knees.	Janet needs to bend her knees. AND Recognition that this increases stopping time, thus reducing the force.	Complete answer including Δp is the same regardless of whether the knees are bent or not.
(c)	Her momentum is not conserved. This is because gravity acts as an external force.	Correct answer with reason.		
2015(3) (a)		All three arrows correct F_g, F_f, F_r and labelled (with directions not perfect). OR Two forces perfectly correct – ignoring 'extras'.	Arrows drawn such that there is a 90° angle between F_r and F_f, and F_g is vertically down and no extra forces.	

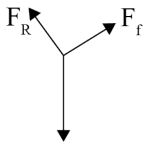
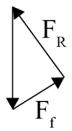
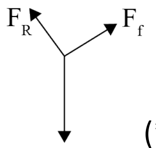
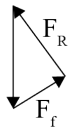
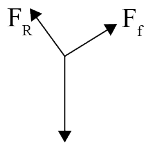
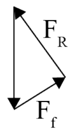
(b)	 Forces are balanced/in equilibrium. So, the component of gravity down the slope = friction force, and the component of gravity into the slope = reaction force.	Forces are balanced. (NB do not accept 'equal')	Complete answer. Accept labelled closed vector triangle with force directions approx. correct as the reason why forces are balanced.	
(c)	F_g =1500 × 9.8 =14700 N Component of gravity acting into the ground = 14 700 cos12° = 14378 N This is equal to reaction force. Component of gravity acting down the slope = 14 700 sin12° = 3056 N Hence friction force acting up the slope = 3056 N. Since car is stationary, component of F_g into the slope = F_r. And component of F_g down the slope = F_f up the slope.	Recognition of the components of gravity acting into the slope = F_r. OR Component of F_g into the slope = Friction force up the slope. OR calculates F_g correctly.	One mistake. E.g. both F_f and F_r calculated correctly, but no statement of which is which.	All correct.
2014(1) (a)	$\text{Impulse} = F \times t$ $= 0.60 \times 9.8 \times 1.2$ $= 7.056 \text{ N s}$ $= 7.1 \text{ N s}$	Correct mathematical solution.		

(b)	No, momentum is conserved only if there is no net outside force Gravity (or air resistance) provides a net outside force.	Correct statement that momentum is not conserved.	Provides reason for statement: EITHER momentum is not conserved when there is a net external force. OR Gravity (or air resistance) provides a net external force	
2014(2) (a)	$W = F \times d$ $W = 120 \times 9.8 \times 0.55$ $W = 650 \text{ J}$	Correct mathematical solution.		

(d)	When he punches the bag, the stopping time is short/with a padded glove, the stopping time of his fist is longer. Impulse = Force × time, so if the impulse is the same, the punch with the glove produces a smaller force. The speed is the same, so the assumption is that the mass of the glove does not significantly affect the momentum of the fist / Δp is constant.	Force is larger without the glove. OR Force is smaller with the glove. OR Impact time is shorter without the glove. OR Impact time is longer with the glove. OR Δp is constant.	Explanation linked to impulse: EITHER Shorter time without glove linked to larger force without glove. OR Longer time with glove linked to smaller force with glove.	Merit plus assumption explained.
2014(3) (a)	$F = mg$ $F = 1100 \times 9.8$ $F = 10\ 780 = 11000$ N	Correct mathematical solution.		$F = mg$ $F = 1100 \times 9.8$ $F = 10\ 780 = 11000$ N

(b)	Even though the car is moving, the acceleration is zero because the net force / sum of the forces acting on the car is zero/forces are balanced.	ONE correct idea.	BOTH ideas linked.	Even though the car is moving, the acceleration is zero because the net force / sum of the forces acting on the car is zero/forces are balanced.
2014(4) (a)	$p = m \times v$ $p = 1100 \times 18$ $p = 19\ 800 = 20\ 000\ \text{kg m s}^{-1}$	Correct mathematical solution AND unit (accept Ns as alternative unit).		
(b)	$\Delta p = p_f - p_i$ $\Delta p = 1100 \times 11 - 1100 \times 18$ $\Delta p = -7700\ \text{kg ms}^{-1}$ $\Delta p = 7700\ \text{kg ms}^{-1}$ in the opposite direction to the direction of motion/backwards/negative sign.	Correct size or direction.	Correct size AND direction.	

(c)	The total energy is conserved / transformed into other form(s). Some of the car's KE is converted to thermal energy (heat). OR friction force does work on the car to reduce KE.	Recognition that total energy is conserved or transformed. OR Some kinetic energy converted to thermal or heat energy.	Recognition that total energy is conserved or transformed. AND Some kinetic energy converted to thermal or heat energy.	
(d)	$P = \frac{\Delta E}{t}$ $\Delta E = (\frac{1}{2} \times 1100 \times 18^2) - (\frac{1}{2} \times 1100 \times 11^2)$ $\Delta E = 111650 \text{ J}$ $P = \frac{111650}{6}$ $P = 19000 \text{ W}$ Alternative solution: $a = \frac{\Delta v}{\Delta t} = \frac{18-11}{6.0} = 1.17 \text{ m s}^{-1}$ $F = ma = 1100 \times 1.17 = 1283 \text{ N}$ $d = (v_f - v_i) = (18+11) \times \frac{6.0}{2} = 87 \text{ m}$ $W = F \times d = 1283 \times 87 = 111\,650 \text{ J}$ $P = \frac{W}{t} = \frac{111\,650}{6.0} = 18\,608 \text{ W}$	Correct calculation of KE. First 2 steps correct.	Correct calculation of change in KE. Calculation of *d* and *W*.	Correct mathematical solution. Correct solution.

Question	**Achievement**	**Merit**	**Excellence**
2013(1) (d)	ONE OF: Net force = 0. Reaction force acts at 90° to surface. Friction acts upwards along surface.  Closed triangle to show balanced forces with correct labels  	TWO OF: Net force = 0. Reaction force acts at 90° to surface AND Friction acts upwards along surface.  (** No contradictory vectors) Closed triangle to show balanced forces with correct labels  	ALL OF: Net force = 0. Reaction force acts at 90° to surface AND Friction acts upwards along surface.  Closed triangle to show balanced forces with correct labels. Or shows that sum of horizontal and vertical components add to zero. 

2013(2) (c)	TWO of: The only unbalanced force acting on the ball is the force of gravity. Gravity acts downwards. This unbalanced force causes the ball to decelerate or accelerate downwards. Velocity at the top is zero.	The only unbalanced force acting on the ball is gravity, which acts downwards. This causes the ball to decelerate or accelerate downwards. Hence the ball slows down to a stop when it reached maximum height.	
2013(3) (a)	$p = mv$ $p = 305 \times 2.4 = 732$ kg m s^{-1} $p = 730$ kg m s^{-1} OR Accept both done separately (576 kg m s^{-1} and 156 kg m s^{-1})		

(b)	ONE OF: - Rubber bumpers reduce the force. - The rubber compresses to increase the time of impact. - Since change in momentum is the same. OR - Rubber bumpers move a distance when compressed, so for the same amount of work done or energy changed, or the same change in velocity, acceleration is decreased due to longer time, so less force is used.	TWO OF: - Rubber bumpers reduce the force. - The rubber compresses to increase the time of impact. - Since change in momentum is the same. OR - Rubber bumpers move a distance when compressed, so for the same amount of work done or energy changed, or the same change in velocity, acceleration is decreased due to longer time, so less force is used.	Rubber bumpers reduce the force. The rubber compresses to increase the time of impact. Since change in momentum is the same. OR Rubber bumpers move a distance when compressed, so for the same amount of work done or energy changed, or the same change in velocity, acceleration is decreased due to longer time, so less force is used.

(c)	Momentum is conserved (240 + 65) 2.4 $\rightarrow$ +(240 + 58)2.7 $\leftarrow$ = (480 + 65 + 58) *v* *732$\rightarrow$ + 804.6$\leftarrow$ = 603 v* OR Solved without adding mass of cart 156 – 156.6 = 0.6 OR Gets 2.5 m s^{-1} by adding	732 $\rightarrow$ + 804.6 $\leftarrow$ = 603 *v* *72.6$\leftarrow$ = 603 v* *OR* *Found velocity without taking mass of cart into consideration* *(v =4.9 x10^{-3} m s^{-1})*	*v* = 72.6 / 603 = 0.12 m s^{-1} $\leftarrow$
(d)(ii)	$E_p = 877.5$ J $F = kx = 78000 \times 0.15$ $F = 11700$ N OR average force = 5850 N OR 9360 with no units	$I = F\Delta t$ $I = 11700 \times 0.80$ $I = 9360$ N s OR I = 4680 N s OR I = 1463 kg m s^{-1}	

2012(1) (a)	Energy		
(b)	Momentum		
(c)	$p_i = p_f$ $65 \times v = 120 \times 5.5$ $v = 10.15$	$mgh = \frac{1}{2}mv^2$ $65 \times 9.8 \times h = \frac{1}{2} \times 65 \times 10.15^2$	h = 5.3 m
2012(3) (a)	Gravitational PE → Kinetic energy OR Kinetic energy → Elastic PE	Gravitational PE → Kinetic energy AND Kinetic energy →Elastic PE	
(b)(i)	The force is upwards.		

(b)(ii)	If the rope is too tight, this will decrease her stopping time. OR The size of force increases. OR The size of her deceleration increases.	If the rope is too tight this will decrease her stopping time and so increase the size of the force acting on her. OR A shorter stopping time will increase the size of her deceleration.	If the rope is too tight this will decrease her stopping time. AND $\Delta p = F\Delta t$, the rope tension does not affect Δp. So a shorter stopping time will increase the size of the upward force acting on her. OR A shorter stopping time will increase the size of her deceleration. $F = ma$ and m is constant. So, a larger deceleration requires a larger upward force on her.

Question	Evidence	Achievement	Merit	Excellence
2011(2) (c)	(16.8 × 72.0) – (8.0 × 0.430) = (72 *x*) + (5.0 × 0.430) 1 209.6 – (3.44 + 2.15) = 72 *x* 1 204.01 = 72 *x* *x* = 16.7 m s^{-1} forward (same as original direction).	[2]Correct answer to 1206.2 kg m s^{-1}.	[2]Correct answer to 1 204.01 kg m s^{-1} OR Correct velocity without direction.	[2]Correct answer including direction.
(d)	An elastic collision is one in which kinetic energy is conserved. An inelastic collision is one in which some kinetic energy is lost (in form of heat to the surroundings.) In order to find out whether a collision is elastic or inelastic, the total kinetic energy before collision and the total kinetic energy after collision are to be calculated. If they are the same, the collision is elastic, if kinetic energy after collision is less/different, then the collision is inelastic.	[1]States one point correctly.	[1]States two points correctly.	[1]States all three points correctly.

(e)	When the change in momentum is the same, the force can be reduced by a longer impact time. Force exerted by Jacquie and her bike on the ball is equal in size but opposite in direction to the force exerted by the ball on the bike and Jacquie. (Since the change in momentum of Jacquie and her bike is equal to the change in momentum of the ball, and they are in contact with each other for the same length of time.)	[1]Less force when time of impact is longer. OR Each object exerts an equal force on the other. OR The direction of force is opposite.	[1]Less force is exerted when time of impact is longer since change in momentum is the same. OR Each object exerts an equal but opposite force on the other.	[1]Less force is exerted when time of impact increases since change in momentum is the same. AND Each object exerts an equal but opposite force on the other.
2011(3) (b)	$P = \frac{W}{t}$ $P = \frac{26\cos 34° \times 4.0}{3}$ $P = 28.7\ \text{W}$	[2]Calculates power using F = 26 N (will get 34.6 W). OR Correct answer to work done using horizontal component of force.	[2]Correct working and answer.	
	Watts or J s^{-1} or N m s^{-1}	[1]Correct unit.		

2010(3) (a)	$d = v_i t + \frac{1}{2} at^2$ $d = 0 + \frac{1}{2} \times 2.21 \times 2.0^2$ $d = 4.42 \text{ m} = 4.4 \text{ m}$	[2]Correct answer.		
(b)	Two significant figures because this is the smallest number of significant figures in the data.	[1]Correct answer.		

(c)	When she lands an upward force causes her to stop. Her momentum change is $\Delta p = F\Delta t$ The size of her momentum change is unaffected so the padded mat causes her to stop in a longer time. This means there is a smaller force acting on her. OR Work must be done to stop her. $W = F \times d$ The size of the work done is unaffected, so the padded mat causes her to stop in a longer distance. This means there is a smaller force acting on her. OR Explains in terms of acceleration: Since change in velocity is over a longer period of time, so less acceleration since $a = \frac{\Delta v}{t}$. Since *F* = *ma*, a smaller acceleration would mean a smaller force when landing on the padded mat.	[1]Decreases the size of the force acting on her body. OR Longer time and hence smaller impact OR Transfers energy over a longer period of time.	[1]Decreases the size of the force acting on her body because stopping time increases. OR Decreases the size of the force acting on her body because stopping distance increases.	[1]Full explanation.

2010(4) (a)	$a = \frac{\Delta v}{\Delta t} = \frac{11-0}{0.25} = 44 \text{ m s}^{-2}$ $F = ma = 5.4 \times 44 = 240 \text{ N}$ OR $F\Delta t = m\Delta v$ $F \times 0.25 = 5.4(11-0)$ $F = 240 \text{ N}$	[2]Correct acceleration. OR Correct Δp	[2]Correct answer.	
(b)	Because friction is negligible there are no net outside forces, so the total momentum remains constant. The momentum of the stationary shot increases because there is an outside (unbalanced) force on it. Momentum gained by stationary shot = momentum lost by thrown shot. OR The 5.4 kg shot transfers some of its momentum to the 4 kg shot.	[1]Total momentum constant. OR Momentum of stationary shot increases.	[1]Achievement plus one explanation.	[1]Full explanation (last sentence is not essential but can provide evidence). *Must have TWO statements and a reason for each statement – one for total momentum and one for momentum of 4 kg shot.
(c)	$\sum p_i = \sum p_f$ $5.4 \times 1.5 \rightarrow = 5.4v + 4.0 \times 2.4 \rightarrow$ $8.1 \rightarrow -9.6 \rightarrow = 5.4v$ $v = 0.28 \text{ m s}^{-1} \quad \leftarrow$	[2]Correct equation and substitution. OR Gets 8.1 and 9.6 kg ms^{-1} correct.	[2]Correct answer to final speed.	[2]Correct answer to final velocity including size and direction.

2009(1) (d)	Not all of the gravitational potential energy is converted to kinetic energy as the ball moves through the air. Some kinetic energy is converted to heat energy lost due to deformation and sound when it hits the ground. Hence not all of the gravitational potential energy is converted to kinetic energy when it rises. The bounce is not perfectly elastic. So more kinetic energy is converted to heat. Since it has less kinetic energy, the height of bounce is less.	[1]Height decreases because ball loses energy.	[1]Achievement plus states not all of the gravitational potential energy is converted to kinetic energy as the ball falls through the air, some energy is converted to heat due to air resistance or friction. OR Not all of kinetic energy is converted to gravitational potential energy when it rises as the bounce is not perfectly elastic.	[1]Merit plus relates the decrease in height as the ball loses energy both during downward motion as well as during the rebound. Hence it does not rise as high.
2009(3) (d)	$F\Delta t = m\Delta v$ $2560 \times t = 0.161(30-(-21))$ $2560 \times t = 0.161 \times 51.0$ $t = \frac{0.161 \times 51.0}{2560}$ $t = 0.0032 s = 3.2 \times 10^{-3}$ s * Can also solve this using *F* = *ma*	[2]Correct substitution but got incorrect answer because Δv is incorrect.	[2]Correct answer.	

(e)	2sf Because the number of sf for speed is 2. This is the number with the least number of sf in the question.	[1]Correct sf.	[1]Correct sf and reason.	
(f)	The moving ball has momentum, which changes when Harry catches the ball. Impulse or change in momentum is a product of the force and time. Stopping the ball involves changing its momentum. The size of the change in momentum does not depend on how he catches it. Since change in momentum is = *Ft*, a longer stopping time means a smaller force. By increasing the time taken, the force is reduced. This is the reason why Harry draws his arm back while catching the ball. Or, could also use Newton's second law reasoning to say that by increasing time, acceleration is reduced thus reducing the force on the hand.	[1]Reduces force on hands.	[1]Achievement plus stopping time increases and thus force on hands reduces. OR Less force and change in momentum remains the same.	[1]Merit plus size of the change in momentum is the product of force and time. Thus a longer time implies a smaller force on the hands. The change in momentum (Δp) stays the same. OR Increasing stopping time would result in smaller acceleration of the ball, thus reducing the force on the hand, since $F=ma$ and change in velocity is the same and $a = \Delta v/t$. Mass stays the same, so if "a" reduces, force decreases as well.

2008(1) (a)	$d = \frac{(v_f + v_i)}{2}$ $d = \frac{(6+8)}{2} \times 3$ $d = 21\,\text{m}$ OR valid alternative.	[2]Correct answer.		
	d = 20 to 1 s.f.	[1]1 sig. fig.		
(f)	For Louise to travel at a constant speed, all forces acting on her must be balanced, hence the net force acting on her is zero. OR If Louise is travelling at a constant speed then her acceleration must be zero, hence according to Newton's second law, $F = ma$, her net force must be zero.	[1]Net force = 0N OR All forces are balanced / in equilibrium.	[1]Links constant speed to balanced forces, hence $F_{net} = 0$ N OR Links constant speed to $a = 0$ m s^{-2}, hence $F_{net} = 0$ N.	

(g)	The only FORCE on the ball is gravity. This is down and constant the whole time. This means the ACCELERATION is constant and downwards even at the top. The VELOCITY is upwards, decreasing, then zero at the top, then downwards increasing.	[1]ONE correct idea.	[1]Any TWO correct ideas.	[1]All THREE ideas clearly explained, AND showing clear understanding of the force/accel at the top, OR equal but opposite velocity at the bottom.
(h)	Δv = 12 – (–8) = 20 (right positive) $a = \frac{\Delta v}{\Delta t} = \frac{20}{0.10} = 200 \text{ m s}^{-1}$ $F = ma = 0.45 \times 200$ $F = 90 \text{ N}$ OR $\Delta p = 0.45(12-(-8) = 9.0$ (right positive) $F = \frac{\Delta p}{\Delta t} = \frac{9.0}{0.10}$ $F = 90 \text{ N}$	[2]Determines the correct magnitude of the change in velocity or change in momentum (using initial – final).	[2]Correct working and determines Δv using $v_{final} - v_{initial}$ then calculates the acceleration OR Correct working and determines Δp using $p_{final} - p_{initial}$ OR All correct except makes an error in the determination of the change in *v* or *p* or the conversion of mass.	[2]Correct working and answer.

(i)	90 N to the left. OR –90 N to the right.	[1]Force and direction are correct and consistent with respect to sign.		
2008(2) (f)	Inelastic means kinetic energy is not conserved / is lost.	[1] Correct answer.		

(g)	Principle of conservation of energy $E_{P \text{ at top}} = E_{K \text{ at bottom}}$ then $E_{P \text{ at top}} = mgh = 55 \times 9.8 \times 4.0$ $E_{P \text{ at top}} = 2156$ $E_{K \text{ at bottom}} = 2156$ $\frac{1}{2} mv^2 = 2156$ $v = \sqrt{\frac{2 \times 2156}{55}}$ $v = 8.85 \text{ m s}^{-1}$ OR $v = \sqrt{2gh}$ $v = \sqrt{2 \times 9.8 \times 4.0}$ $v = 8.85 \text{ m s}^{-1}$ THEN Principle of Conservation of momentum $p_{before} = p_{after}$ $m_T v_T = (m_T + m_R)\, v_{TR}$ $55 \times 8.85 = (55 + 65)\, v_{TR}$ $486.99 = 120\, v_{TR}$ $v_{TR} = \frac{486.99}{120} = 4.06 \text{ m s}^{-1}$	[2]Correctly determines E_P.	[2]Correctly working and determines initial velocity.	[2]Correct working and answer.

(h)	Momentum is NOT conserved, as there is an external force due to gravity acting on him resulting in an increase in his momentum / velocity.	[1]Momentum is not conserved as there is an external force (the system is not isolated). OR Momentum is not conserved as Tahi's speed/momentum increases.	[1]Momentum is not conserved as there is an external force hence Tahi's speed / momentum increases.	
(i)	2 sf	[1]2sf (any correctly rounded answer)		
2007(3) (e)	Momentum is conserved. $(33 \times 3.6) + (35 \times 2.0) = (33 \times 2.4) + 35v$ $118.8 + 70 = 79.2 + 35v$ $v = 3.13 \text{ m s}^{-1}$. E_k of trolley B = $\frac{1}{2} mv^2 = 0.5 \times 35 \times 3.13^2$ E_k =171.6 J	[2]States that momentum is conserved (maths or words). OR Determines Total p_{before} OR Total p_{after} OR Δp_A OR Δp_B	[2]Correct answer for velocity.	[2]Merit plus correct calculation of kinetic energy of trolley B. (Do not accept rounding for excellence if it causes a change in the significant figure answer.

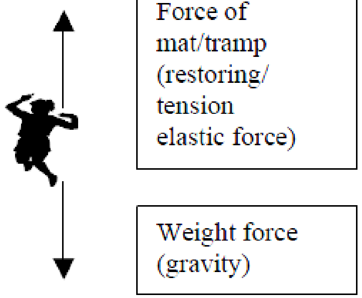
(f)	Momentum is conserved assuming the absence of external forces such as friction or people pushing.	[1]Isolated system OR No external forces. OR No friction / push.	[1]Links an isolated system / absence of external forces to the friction / push. OR Identify both external forces.	
(g)	Elastic collisions Momentum is conserved, and Kinetic energy is conserved. Inelastic collisions Momentum is conserved, but Kinetic energy decreases as it is converted to heat/sound/elastic.	[1]Momentum is conserved in all collisions. OR E_K is conserved in Elastic collisions. OR E_K is not conserved in inelastic collisions.	[1]Momentum is conserved in all collisions AND Both kinetic energy statements.	[1]Clear definitions of elastic and inelastic in terms of momentum and kinetic energy and identifies that E_K is transformed to heat/sound/elastic in inelastic. (DO NOT ACCEPT ALL kinetic energy for E).
2006(4) (a)	Momentum	[1]Correct answer.		

(b)	$\Delta v = v_f - v_i = 2 - 8 = -6$ $\Delta p = m \times \Delta v$ $= 950 \times (-6)$ $= -5700$ kg m s^{-1} (or 5700 kg m s^{-1} to the left/backwards/west) OR $P_{before} = m_c v_{ci} = 950 \times 8 = 7600$ kg m s^{-1} $P_{after} = m_c v_{cf} = 950 \times 2 = 1900$ kg m s^{-1} $\Delta p = p_{cf} - p_{ci} = 1900 - 7600$ $\Delta p = -5700$ kg m s^{-1} (or 5700 kg m s^{-1} to the left/backwards/west)	[2]Calculates the momentum of the car before OR after the collision.	[2]Correct size of the change is calculated only. OR Correct size is calculated BUT the direction is incorrect. (consistent with the sign)	[2]Correct working (using change = final – initial) and final answer is a valid physics statement with respect to sign and direction.
(c)	$\Delta p = m \times \Delta v = 5700 = 1700 \times v$ $v = 3.4$ m s^{-1} OR$950 \times 8 + 0 = 950 \times 2 + 1700 \times v$ $v = 3.4$ m s^{-1}	[2]Recognition that the SIZE of the change in momentum $\Delta p_{van} = \Delta p_{car}$ OR Total p_i = Total p_f	[2]Correct working and answer.	

(d)	$\Delta p = F\,\Delta t$ $\Delta t = \frac{\Delta p}{F}$ $\Delta t = \frac{5700}{3800}$ $\Delta t = 1.5$ s OR $a = F/m = 3800/950 = 4$ m s^{-2} $v_f = v_i + at$ $2 = 8 - 4t$ $t = -6/-4 = 1.5$ s	[2]Correct working and answer.		
(e)	By Newton's 1st Law a net force is required to cause a change in velocity and as the bag is not attached to the car it will not experience a decelerating force. Hence the bag will continue to move at a constant speed in a straight line, assuming that the friction between the bag and the front seat is negligible, until it experiences a force from the front of the car to change its motion.	[1]The bag continues to move at a constant speed/bags momentum remains the same. OR No forces act on the bag to slow it down.	[1]Achieved plus Links constant speed / constant momentum with absence of a force.	[1]Merit plus States assumption that the force due to friction is negligible. OR Until a force is applied by collision with the dashboard to change its velocity /momentum.

(f)	Crumple zones cause the collision time to increase. Change in momentum remains the same. So a longer collision time for the same momentum means a smaller force on the occupants as $F = \Delta p/t$. OR Crumple zone increases stopping distance, therefore the time of the collision increases. For the same Δv, if Δt increases then Δa decreases. As F=ma then F must also decrease resulting in less force on the occupants.	[1]Increases stopping time. OR Reduces the force.	[1]Achieved PLUS Links increasing the time with reducing the force.	[1]Merit PLUS Recognises that Δp remains the same (if using momentum considerations to solve). OR Merit plus Recognises that Δv remains the same (if using Newton's 2nd law to solve).
2005(2) (a)	$p_i = p_f$ $m_i v_i = m_f v_f$ $1200 \times v = (1200 + 1500) \times 4$ $\Rightarrow v = \frac{2700 \times 4}{1200} = 9.0 \text{ ms}^{-1}$	[2]Correct expression for p_i. OR Correct calculation of combined momentum after the collision.	[2]Correct answer	
(b)	Momentum	[1]Correct answer		

(c)	No external forces were acting / isolated system	[1]Correct answer.		
(d)	$m\Delta v = F\Delta t$ $1200 \times (9.0 - 4.0) = F \times 0.50$ $\Rightarrow F = \frac{1200 \times 5}{0.50} = 1.2 \times 10^4$ N **OR** $1500 \times 4.0 = F \times 0.50$ $\Rightarrow F = \frac{1500 \times 4}{0.50} = 1.2 \times 10^4$ N **OR** $a = \Delta v \div \Delta t = 4\text{-}0/0.50 = 8.0\ ms^{-2}$ $F = ma = 1500 \times 8.0 = 12\ 000$ N	[2]Any reasonable attempt TO APPLY Newton's Second Law.	[2]Correct calculation of EITHER the momentum lost by the car OR the momentum gained by the van OR the acceleration of the van OR the deceleration of the car	[2]Correct answer.
(e)	E.g. Crumple zones, airbags, seat belts, collapsible steering wheel, all reduce the average force exerted on the driver during the impact by increasing the time taken for the driver to come to rest.	[1]TWO correct features named (Note: not ABS brakes). Can accept head restraints or side intrusion bars here – but explanations differ)	[1]Achievement plus: these features reduce the force on the driver. OR Increase the stopping time.	[1]Achievement plus BOTH the force decreases because the stopping time increases.

(f)	$E_{K(\text{before})} = \frac{1}{2}mv^2 = \frac{1}{2} \times 1200 \times 9.0^2$ $= 48600$ J $E_{K(\text{after})} = \frac{1}{2}mv^2 = \frac{1}{2} \times 2700 \times 4.0^2$ $= 21\ 600$ J Kinetic energy is lost so the collision is inelastic.	[2]Correct calculation of kinetic energy before OR after the collision.	[2]Correct calculation of BOTH kinetic energies (consequential).	
		[1]States inelastic collision because the car and the van stick together (but no relevant calculation).	[1]Calculates BOTH E_K but does not compare AND states that collision is inelastic.	[1]Compares kinetic energy E_K (before) > E_K (after) AND links clearly to lost E_K hence collision is inelastic.
2004(3) (a)(i)		[2]Correct answer. (Ignore sign)		
(a)(ii)	 (Length of arrows not relevant)	[1]Both forces drawn and labelled correctly, upward force above mat, weight shown as a pull force. (Do not accept support/reaction/ normal/thrust nor lift for the upward force.)		

2004(4) (c)	$75 \times 6.0 = (75 + 55)v$ $v = \frac{75 \times 60}{75+55} = \frac{450}{130} = 3.5 \text{ m s}^{-1}$	[2]Correct calculation of Jon's momentum before the collision. *OR* correct expression for p_f	[2]Correct answer	
(d)	Conservation of momentum. Total momentum does not change during the collision. The assumption is that no external force acts on the skaters (e.g. skaters do not push/ice has no friction).	[1]Conservation of momentum	[1]Achieved *plus* absence of an external force (saying "no friction" is not enough)	

Level 2 Physics: AS 91171 replaced AS 90255.

The Mess that is NCEA Assessment Schedules….

In 90255, from 2003 to 2011, there was an Evidence column with the correct answer and Achieved, Merit and Excellence columns explaining the required level of performance to get that grade. Each part of the question (row in the Assessment Schedule) contributed a single grade in either Criteria 1 (Explain stuff) or Criteria 2 (Solve stuff). From 2003 to 2008, sometimes the NCEA shaded columns that were not relevant to that question. – Sorry not all the 2004 answers are here.

In 91171, from 2012 onwards, the answers/required level of performance are now within the Achieved, Merit and Excellence columns. Each part of a question contributes to the overall Grade Score Marking of the question and there are no longer separate criteria. There is no shading anymore. Things are black and white. At least their equation editor has stopped displaying random characters over the units.

And in 2013, with 91171, we still have no Evidence column with the correct answer and Achieved, Merit and Excellence columns explaining the required level of performance to get that part – even though the other two Level 2 Physics external examinations do!!

And now in 2014 - 2017, we have the Evidence column back……