Level 3 Physics: Demonstrate understanding of mechanical systems – Linear Mechanics - Answers

In 2013, **AS 91524** replaced **AS 90521.**

The Mess that is NCEA Assessment Schedules….

In AS 90521 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, the NCEA shaded columns that were not relevant to that question.

In 91524, from **2013 onwards**, 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. There is no spoon. At least their equation editor has stopped displaying random characters over the units.

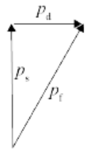
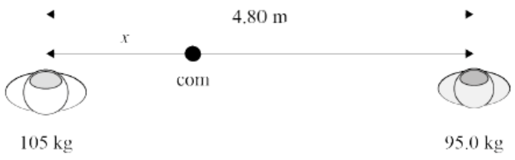
For 2019:

NØ	N1	N2	A3	A4	M5	M6	E7	E8
0	1A	2A or 1M	3A or 1A +1M or 1E-	4 A or 2A + M or 2M or 1A+1E-	1A + 2M or 1M+1E- or 3A +1M or 2A + 1E-	2A + 2M or 3M or 3A + 1E- or 1A +1M + 1E-	2M+1E- or 2A +1M + 1E- or A + 2M + 1E-	A + 2M +E

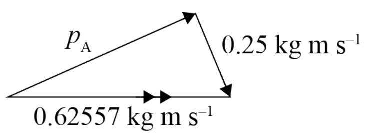
Other combinations are also possible using a=1, m=2 and e=3. However, for M5 and M6, at least one Merit question needs to be correct (maximum 6). For E7 or E8, at least one Excellence needs to be correct (maximum 8). **Note: E- and E only applies to the E7 and E8 decision. <----** It's good that NCEA gets clearer and clearer after 16 years!

Question	Evidence	Achievement	Merit	Excellence
2019(1) (a)	Linear momentum, velocity of CoM, total energy. *(Accept Momentum, even if it is not described as linear momentum)*	• Any ONE.		

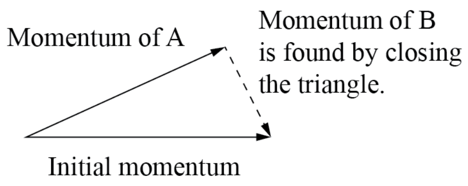
(b)	Total p before = 60 x 1.8 = 108 kg m s^{-1} = total p after (conservation of momentum law) $p_{Ally} = \sqrt{108^2 - 66^2} = 85.486$ kg m s^{-1} $v_{Ally} = \frac{p}{m} = \frac{85.486}{50} = 1.70972 = 1.71\text{ m s}^{-1}$	• Calculates Chris's momentum before. OR • Calculates total momentum before. OR • Calculates Ally's velocity with incorrect momentum.	• Correct working. (Note, NOT answer as this is a SHOW question).	
2018(1) (c)(i) (ii)	$m_1x = m_2(1.08\times10^4 - x)$ $1.50\times10^2 \times x = 20\times1.08\times10^4 - 20x$ $170x = 20\times1.08\times10^4$ $x = \frac{20\times1.08\times10^4}{170} = 1270\text{ m}$ OR $x_{com} = \frac{m_1x_1 - m_2x_2}{m_1 + m_2}$ $x_{com} = \frac{1.50\times10^2\times0 + 20\times1.08\times10^4}{20+150} = 1270\text{ m}$ Centre of mass will continue to move with uniform speed and direction since there are no unbalanced forces **in the horizontal direction.** **Accept 'Closed system' or 'no external forces' in the explanation)**	Correct method with incorrect calculation (could be a substitution error OR measured from the wrong end) OR States that the velocity of the centre of mass will be constant. (ignore the need for the word "horizontal")	Correct Centre of Mass calculation AND States that the motion of the centre of mass will continue at constant velocity because there are no unbalanced horizontal force. (Ignore the need for the word "horizontal".)	

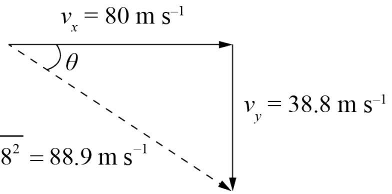
(d)	 $v=\sqrt{\frac{GM}{r}}=7.613\times10^{3}\ \text{m s}^{-1}$ $p_s=mv=150\times7.61\times10^{3}$ $=1.142\times10^{6}\ \text{kg m s}^{-1}$ $p_d=mv=20.0\times7.61\times10^{3}$ $=1.523\times10^{5}\ \text{kg m s}^{-1}$ $p_f^{2}=p_d^{2}+p_s^{2}$ $p_f^{2}=(1.142\times10^{5}\ \text{kg m s}^{-1})^{2}+(1.523\times10^{5}\ \text{kg m s}^{-1})^{2}$ $p_f=\sqrt{1.32735\times10^{12}}\ \text{kg m s}^{-1}$ $=1.152\times10^{6}\ \text{kg m s}^{-1}$ $v_f=\frac{p_f}{\text{mass}}=\frac{1.152\times10^{6}}{170}=6776\ \text{m s}^{-1}=6780\ \text{m s}^{-1}$ Direction $\tan^{-1}\left(\frac{1.523\times10^{5}\ \text{kg m s}^{-1}}{1.142\times10^{6}\ \text{kg m s}^{-1}}\right)=7.60°$ Note: Look for an angle of 82.4°. This is the complement of 7.6°.	Calculates either of the initial momentum values correctly OR Calculates final momentum correctly using wrongly calculated initial values of momentum (no direction required) OR Calculates the angle of the new momentum correctly (Allow follow on error for velocity from Q1b for all of the above.)	Correct magnitude of final momentum. (Allow follow on error for velocity from Q1b.)	Calculates final velocity including direction. (E) Calculates final velocity including direction with follow on error from Q1b. (E) Calculates the final SPEED (no direction). (E–) Calculates the final SPEED with a follow-on error from 1b (no direction). (E–) (This can be checked quickly using final velocity is 89% of the orbital velocity that the candidate has used.)
2017(1) (a)	 $m_1x=m_2(4.80-x)$ $105\times x=95.0\times4.80-95.0\times x$ $200\times x=95.0\times4.80$ $x=\frac{95.0\times4.80}{200}=2.28\ \text{m}$ OR $x_{\text{com}}=\frac{m_1x_1+m_2x_2}{m_1+m_2}$ $x_{\text{com}}=\frac{105\times0+95.0\times4.80}{105+95.0}$ $x_{\text{com}}=2.28\ \text{m}$	Correct method with incorrect calculation.	Correct answer.	

(b)	The centre of mass keeps moving at constant velocity.	Correct answer.		
(c)	$p_{Sam} = 105 \times 1.2 = 126 \text{ kg m s}^{-1}$ $p_{Sylvia} = 95 \times 1.4 = 133 \text{ kg m s}^{-1}$ $\Sigma p = \sqrt{126^2 + 133^2} = 183 \text{ kg m s}^{-1}$ $v = \frac{p}{m} = \frac{183}{200} = 0.92 \text{ m s}^{-1}$	Total momentum calculated correctly. OR Correct method with two-dimensional momentum but allow follow on error for A.	Total momentum and speed calculated correctly.	
2015(3) (a)	The centre of mass accelerates towards the ground as a single force (weight) acts upon it. Linear momentum increases due to the external force (weight), causing an increase in vertical velocity.	Centre of mass accelerates downwards. OR Linear momentum increases because the vertical velocity is increasing. *(Accept velocity is increasing.)*	Centre of mass accelerates downwards. AND Linear momentum increases due to external force (weight) causing an increase in vertical velocity. *(Accept Momentum increases because velocity increases and the net (external) force is not zero.)*	
2014(3) (a)	$p_{system} = (m_A + m_B) \times v_{com} = (0.517 + 0.684) \times v_{com}$ $p_{system} = p_A + p_B = 0.517 \times 1.21 + 0 = 0.62557$ $v_{com} = \frac{1.21 \times 0.517}{0.517 + 0.6841} = 0.52087 = 0.521 \text{ m s}^{-1}$ $= 0.521 \text{ m s}^{-1}$	$P = mv = 0.62557$ OR evidence of correct number calculated e.g. $\frac{5.17 \times 1.21}{0.517 + 0.684} = 0.52087$	$p = mv$ OR $m_1v_1 + m_2v_2 =$ $(m_1 + m_2)\, v_{COM}$ OR $p_{COM \text{ or } TOTAL} = p_A + p_B$ AND Substitution into equation to find correct answer.	

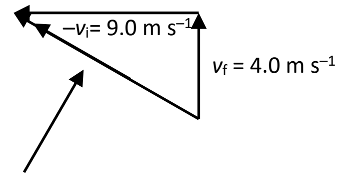
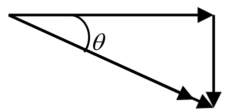
(b)(i)	Momentum is conserved, so the size of the change of momentum on disc A is equal to the size of the change in momentum of disc B. As B had no momentum to start with, its final momentum must be equal to the change in momentum. $\Delta p = mv \Rightarrow v = \frac{0.250}{0.684} = 0.365 \text{ m s}^{-1}$	Momentum is conserved. OR $\Delta p_B = \Delta p_A$ (In words, or equations, or by stating $\Delta p_B = 0.250$) OR Statement of Newton 3rd law, $\Delta p = F\Delta t$ OR $p = mv$ and $\frac{0.250}{0.684} = 0.365497$	Momentum is conserved OR $\Delta p_B = \Delta p_A$ (In words, or equations, or by stating $\Delta p_B = 0.250$) OR Statement of Newton 3rd law, $\Delta p = F\Delta t$ AND $p = mv$ and $\frac{0.250}{0.684} = 0.365497$	
(b)(ii)	$p_{system} = 0.62557 \text{ kg m s}^{-1}$ $p_{system} = p_A + p_B$  $p_A = \sqrt{0.62557^2 - 0.25^2} = 0.57344$ $= 0.573 \text{ kg m s}^{-1}$	*p* = *mv* equation used correctly for some momentum. *ONLY if no credit given for (a) or (b)(i).*	Shows Pythagoras with momentum, wrong answer. OR Correct vector diagram with labels or numbers - diagram either Δp or total *p*. (Arrows not needed) wrong answer.	Shows evidence of Pythagoras or vector diagram. AND Correct answer. *Carry on error from wrong p in 3a or 3b(i) OK.*

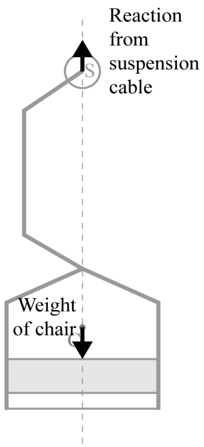
(c)	The only forces that will be acting on the discs will be tension force in the cord. As this is internal force acting within the system, neither the momentum of the system nor the velocity of the centre of mass of the system will change. No friction therefore no external force acting on the system thus momentum is conserved.	No friction / frictionless. OR No external forces. Tension / force on string is an internal force. OR Forces due to cord oppose / cancel. *(Accept closed system in place of "no external forces".)*	No friction, no external forces. OR No external forces because force due to string is internal. OR No external forces because string forces oppose / cancel each other. *(Accept closed system in place of "no external forces".)*	No friction therefore no external forces therefore p is conserved AND Force of the string is internal. OR String forces oppose / cancel each other. *(Accept closed system in place of "no external forces")*
2012(3) (a)	Momentum is conserved in the horizontal direction because there are no external forces. Kinetic energy is not conserved because the elastic potential energy of the spring has been converted into kinetic energy / the kinetic energy of the system has increased.	[1]Momentum is conserved and kinetic energy is not conserved plus some idea why kinetic energy is not conserved. OR kinetic energy not conserved is linked to the explosion of the spring.	[1]Momentum is conserved and kinetic energy is not conserved because energy is gained from the spring. OR Full explanation for why kinetic energy is not conserved.	[1]Correct and full explanation.
(b)	$p_{\text{before}} = p_{\text{after}} = mv = 0.105 \times 67 = 7.035 = 7.04$ kg m s^{-1}	[2]Correct answer.		

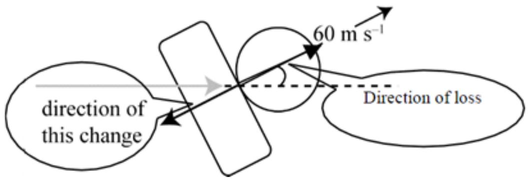
(c)	 • Momentum of particle A can be calculated: $p_A = m_A v_A$ or p_A = 0.080 × 0.080 = 6.40 • Initial momentum equals final momentum calculated in (b). • Correct method of finding p_B using vectors, could use vector components / scale drawing of triangle / cosine rule. • $p_A = m_B v_B$, so knowing the mass of B from $m_{ball} - m_A$ ie 0.105 – 0.80 = 0.025 kg $v_B = \frac{p_B}{0.025}$	[1 or 2]Momentum vector diagram drawn and each vector labelled with variable name.	[1 or 2]Momentum vector diagram drawn, values given for p_A and p_i, θ_A labelled.	[1 or 2]Momentum vector diagram plus explanation of how to use it to find velocity.
(d)	Impulse is caused by the force of gravity. The effect of the impulse is to increase the vertical momentum but not the horizontal momentum, which means that the total momentum of the ball has increased.	[1]Impulse is caused by the force of gravity. OR Force of gravity causes an increase in vertical momentum.	[1]Impulse is caused by the force of gravity which means the vertical component of the velocity / momentum increases. OR The effect of the impulse is to increase the vertical momentum but not the horizontal momentum.	[1]Impulse is caused by the force of gravity and its effect is to change the final momentum of the ball by increasing its vertical component.

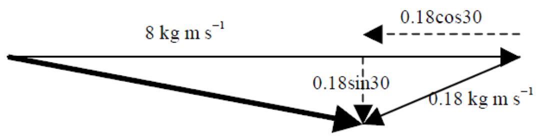
(e)	Impulse = Δp_y Initial p_y is zero, so p_y = impulse = 3.1 Initial $v_y = \frac{p_y}{m} = \frac{3.1}{0.08} = \mathbf{38.8\ m\ s^{-1}}$  $v = \sqrt{80^2 + 38.8^2} = 88.9\ \text{m s}^{-1}$ $\tan\theta = \frac{38.8}{80}$ $\theta = 25.9°$ (Question can be answered using momentum vectors.)	[2]Correct vertical velocity.	[2]Correct velocity	[2]Correct velocity and angle.
2010(2) (a)	The only forces acting to bring about the change in position are internal forces.	[1]Good idea of no external forces acting.		
(b)	$11x = 55(13.2 - x)$ $x = \frac{13.2}{\left(\frac{11}{55} + 1\right)} = 11.0\ \text{cm}$	[2]Correct working		
(c)	$v = (3.5\ \text{m s}^{-1}\rightarrow + 1.8\ \text{m s}^{-1}\downarrow)$ $= \sqrt{3.5^2 + 1.8^2} = 3.9357 = \mathbf{3.94\ m\ s^{-1}}$	[2]Correct answer.		

(d)	$F = ma = \frac{m\Delta v}{t}$, OR $\Delta p = Ft \Rightarrow F = \frac{m\Delta v}{t}$ $\Delta v = v_i$ ($v_f = 0$) $\Rightarrow F = 66 \times \frac{3.9357}{0.835}$ = 311 N	[2]Correct acceleration / correct change in momentum / correct force using m = 55 kg.	[2]Correct answer.	
(e)	$\Delta p = Ft$. The vertical speed is half the horizontal speed, and so change in vertical momentum is half the change in vertical momentum. However, the vertical stopping time is one tenth the horizontal stopping time and so the upward force needed to stop the vertical motion will be much greater than the horizontal friction force needed to stop the horizontal motion.	[1]Shortness of the vertical stopping time identified as the key issue. OR [2]Correct calculation of average horizontal or vertical force.	[1]Short stopping time linked to the need for a large force.	[1]Answer shows understanding of how the difference in stopping times has greater significance than the difference in momentums.
2009(4) (a)	$v_{CofM} = \Sigma p/\Sigma m$ = 1.31/ (0.146 + 0.165) v_{CofM} = 4.21 m s^{-1} OR v_{CofM} = ((9 x 0.146) + (0 x 0.165)) / 0.311 = 4.23 m s^{-1}		[2]Correct answer. v = 4.21 m s^{-1} OR v = 4.23 m s^{-1}	
(b)	Velocity of centre of mass remains constant because there are no external forces.	[1]Remains constant.	[1]Remains constant due to one of: no external forces **or** Momentum is conserved	

(c)	 $\Delta v = \sqrt{(9^2 + 4^2)} = 9.85$ m s^{-1}	[2] Correct answer. $\Delta v = 9.85$ m s^{-1}		
(d)	Δp for ball 1 = $m\ \Delta v$ = 0.146 × 9.85 = 1.438 kg m s^{-1} Δp for ball 2 = $-\Delta p$ for ball 1 p_i for ball 2 = 0 p_f for ball 2 = 1.438 kg m s^{-1} v_f for ball 2 = 1.438/ 0.165 = 8.71 m s^{-1} Direction:  tan θ = 4/9 θ = 24.0° to the original direction of ball 1	[2]Correct direction θ = 24.0° **OR** Uses a vector diagram Vector diagram requires 2 arrows	[2]Correct velocity and incorrect direction v = 8.69 to 8.72 m s^{-1} **OR** Correct Δp of ball 2 Δp = 1.434 – 1.438	[2]Correct velocity and direction v = 8.69 to 8.72 m s^{-1} θ = 24.0°

(e)	Sam only considered linear kinetic energy. In reality the balls also rotate, and so have rotational kinetic energy. During the collision, some rotational kinetic energy from ball 1 could be transferred as linear kinetic energy, explaining the apparent increase in energy. Other possibilities could include an explosive device / way of adding energy from another form during the collision or having the table on a slope so that gpe was being converted to ke.		[1]Plausible reason stated E.g.: Kinetic: Rotation is the cause Gravitational: Sloping table or ball 2 sitting on a bump Chemical: Explosive device of some type. Other: Ball under stress breaks apart. Or any system where external energy is added to the system.	[1]Plausible reason + explanation of the energy transfer. E.g.: Kinetic: $E_{k(rot)}$ ball 1 transferred to $E_{k(linear)}$ ball 2. Gravitational: The $E_{p(grav)}$ is transferred in to $E_{k(linear)}$ Chemical: Chemical energy to $E_{k(linear)}$ Other: Elastic energy to $E_{k(linear)}$ An energy that is added should be from an external source except $E_{k(rot)}$
2008(2) (a)		[1]Forces correctly labelled Can be through COM. (should be roughly equal in length).		

(b)	Chair moves because of unbalanced torque. Due to centre of mass to the right of the suspension cable / weight of skier causes torque. Torque is force × distance between the line of action of the force and the pivot. Net torque causes angular acceleration. Hangs in new position where new centre of mass is below suspension point, so there is no net torque and no angular acceleration.	[1]Any of: COM moved to the right (towards X) The **new** COM now (moved to be) below the suspension point Weight of person causes a torque A "couple: causes a torque	[1]Reason for movement Produces a torque Torque causes rotation of the chair (in clockwise direction) about pivot	[1]Reason for equilibrium Gives reason why the chair is in equilibrium using torques (see below) Justifies why the COM is now under the pivot - balanced torque - no resultant torque
2008(4) (c)(i)	Momentum gained by the ball $p = mv = 3 \times 10^{-3} \times 60 = 0.18$ kg m s^{-1}, this equals momentum lost.  	[2]Correct calculation of p (0.18 kgms^{-1}) OR Correct direction Accept either directions: Δp or momentum loss	[2]Both magnitude and direction correct Accept either directions: Δp or momentum loss	

(c)(ii)	Initial $p = 40 \times 0.2 = 8$ kg m s^{-1} to the right.  $p_{\text{final}}^2 = (8 - 0.18\cos30)^2 + (18\sin30)^2 = 61.5$ $v = \frac{p_{\text{final}}}{m} = \frac{7.85}{0.2} = 39.25 \text{ m s}^{-1}$ (or use cosine rule) $\theta = \tan^{-1}\left(\frac{0.18\sin30}{8 - 0.18\cos30}\right) = 0.88°$	[2]Has incorrect vector diagram but uses it to give some explanation about why change is negligible Must use momentum diagram as part of their explanation (not just a velocity diagram)	[2]A correct consistent vector diagram or analysis (from 4c(i))	[2]A correct vector diagram or analysis and uses correct explanation about why change negligible
(c)(iii)	Because (in the collision) the change of momentum of the club head and the golf ball is unchanged and the ball is much lighter, the gain in speed of the ball is much greater than the decrease in *v* of the club head. or The club and the head experience the same force. However, as the mass of the club head is greater than the mass of the ball the acceleration of the ball will be higher ($F = ma$) Therefore, the ball will travel faster	[1]States that momentum is conserved	[1]relates change of momentum of golf club head to golf balls velocity OR Mentions that any of these is the same in collision –*F* force –*Ft* impulse –Δp change in momentum. on ball and club head	
2007(1) (a)	$p = (1.50 + 0.25) \times 5.4 = 9.45$	[2]Correct working		

(b)	Before the collision the jack is stationary, so the momentum of the bowl is the momentum of the system.	[1]Idea that the stationary jack is a key issue.	[1]Idea that the momentum of the system is the sum of the individual momentums, and that the momentum of the jack is zero.	
(c)	$d_j = d \times \frac{m_b}{m_b + m_j}$ $= 10.0 \times \frac{1.50}{1.50 + 0.25} = 8.57143$		[2]Correct working.	
(d)	$t = \frac{d}{v} = \frac{8.57143}{5.4} = 1.58730$ **= 1.6 s**		[2]Correct answer.	
(e)	$\cos\theta = 8.7 \div 9.45$ $\Rightarrow \theta = 22.981$ **= 23°**		[2]Correct answer.	
(f)	$\Delta p(\text{bowl}) = Ft$ $\Delta p(\text{bowl}) = \sqrt{9.45^2 - 8.7^2} = 3.689512$ $\Rightarrow F = \frac{3.689512}{0.025}$ = 147.5805 N **= 150 N**	[1]Correct answer shows recognition that the Δp of the bowl is the final p minus the initial p.	[2]Correct Δp(bowl).	[2]Correct answer