Pearson Edexcel

Mark Scheme (Results)

January 2019

Pearson Edexcel International Advanced Level In Mechanics M3 (WME03/01)

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January 2019
Publications Code WME03_01_1901_MS

General Marking Guidance

- All candidates must receive the same treatment. Examiners must mark the first candidate in exactly the same way as they mark the last.
- Mark schemes should be applied positively. Candidates must be rewarded for what they have shown they can do rather than penalised for omissions.
- Examiners should mark according to the mark scheme not according to their perception of where the grade boundaries may lie.
- There is no ceiling on achievement. All marks on the mark scheme should be used appropriately.
- All the marks on the mark scheme are designed to be awarded. Examiners should always award full marks if deserved, i.e. if the answer matches the mark scheme. Examiners should also be prepared to award zero marks if the candidate's response is not worthy of credit according to the mark scheme.
- Where some judgement is required, mark schemes will provide the principles by which marks will be awarded and exemplification may be limited.
- When examiners are in doubt regarding the application of the mark scheme to a candidate's response, the team leader must be consulted.
- Crossed out work should be marked UNLESS the candidate has replaced it with an alternative response.

PEARSON EDEXCEL IAL MATHEMATICS

General Instructions for Marking

1. The total number of marks for the paper is 75

2. The Edexcel Mathematics mark schemes use the following types of marks:

   - **M** marks: Method marks are awarded for 'knowing a method and attempting to apply it', unless otherwise indicated.
   - **A** marks: Accuracy marks can only be awarded if the relevant method (M) marks have been earned.
   - **B** marks are unconditional accuracy marks (independent of M marks)
   - Marks should not be subdivided.

3. Abbreviations

   These are some of the traditional marking abbreviations that will appear in the mark schemes.

   - bod – benefit of doubt
   - ft – follow through
   - the symbol $\sqrt{}$ will be used for correct ft
   - cao – correct answer only
   - cso - correct solution only. There must be no errors in this part of the question to obtain this mark
   - isw – ignore subsequent working
   - awrt – answers which round to
   - SC: special case
   - oe – or equivalent (and appropriate)
   - d… or dep – dependent
   - indep – independent
   - dp decimal places
   - sf significant figures
   - $\ast$ The answer is printed on the paper or ag- answer given
   - $\llcorner$ or d… The second mark is dependent on gaining the first mark

4. All A marks are 'correct answer only' (cao.), unless shown, for example, as A1 ft to indicate that previous wrong working is to be followed through. After a misread however, the subsequent A marks affected are treated as A ft, but manifestly absurd answers should never be awarded A marks.

5. For misreading which does not alter the character of a question or materially simplify it, deduct two from any A or B marks gained, in that part of the question affected.

6. If a candidate makes more than one attempt at any question:
   - If all but one attempt is crossed out, mark the attempt which is NOT crossed out.
   - If either all attempts are crossed out or none are crossed out, mark all the attempts and score the highest single attempt.

7. Ignore wrong working or incorrect statements following a correct answer.

General Principles for Mechanics Marking

(But note that specific mark schemes may sometimes override these general principles)

- Rules for M marks: correct no. of terms; dimensionally correct; all terms that need resolving (i.e. multiplied by cos or sin) are resolved.

- Omission or extra g in a resolution is an accuracy error not method error.

- Omission of mass from a resolution is a method error.

- Omission of a length from a moments equation is a method error.

- Omission of units or incorrect units is not (usually) counted as an accuracy error.

- DM indicates a dependent method mark i.e. one that can only be awarded if a previous specified method mark has been awarded.

- Any numerical answer which comes from use of g = 9.8 should be given to 2 or 3 SF.

- Use of g = 9.81 should be penalised once per (complete) question.

  N.B. Over-accuracy or under-accuracy of correct answers should only be penalised *once* per complete question. However, premature approximation should be penalised every time it occurs.

- Marks must be entered in the same order as they appear on the mark scheme.

- In all cases, if the candidate clearly labels their working under a particular part of a question i.e. (a) or (b) or (c),……then that working can only score marks for that part of the question.

- Accept column vectors in all cases.

- Misreads – if a misread does not alter the character of a question or materially simplify it, deduct two from any A or B marks gained, bearing in mind that after a misread, the subsequent A marks affected are treated as A ft

- Mechanics Abbreviations

  M(A) Taking moments about A.

  N2L Newton’s Second Law (Equation of Motion)

  NEL Newton’s Experimental Law (Newton’s Law of Impact)

  HL Hooke’s Law

  SHM Simple harmonic motion

  PCLM Principle of conservation of linear momentum

  RHS, LHS Right hand side, left hand side.

Jan 2019 IAL **WME03 M3**
Mark Scheme

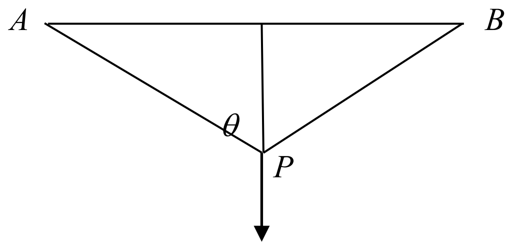
Question Number	Scheme	Marks
1.	$v\dfrac{dv}{dx}=\dfrac{7}{2}-2x$	M1
	$\dfrac{1}{2}v^2=\dfrac{7}{2}x-x^2\ (+c)$	A1
	$x=0\quad v=3\ \Rightarrow c=\dfrac{9}{2}$	A1
	$v=0\qquad 0=\dfrac{7}{2}x-x^2+\dfrac{9}{2}$	M1
	$2x^2-7x-9=0$	
	$(2x-9)(x+1)=0$	M1
	$x=4.5$ oe	A1cso
	By definite integration:	
	$v\dfrac{dv}{dx}=\dfrac{7}{2}-2x$	M1
	$\int v\,dv=\int\left(\dfrac{7}{2}-2x\right)dx\Rightarrow\left[\dfrac{1}{2}v^2\right]_3^0=\left[\dfrac{7}{2}x-x^2\right]_0^X$	A1A1
	$(0)-\dfrac{1}{2}\times3^2=\dfrac{7}{2}X-X^2\ (-0)$	M1
	$2X^2-7X-9=0\Rightarrow X=4.5$ oe	M1A1cso
		[6]
M1	For an equation of motion with the acceleration in the form $v\dfrac{dv}{dx}$ oe May be implied by sight of $(1/2)v^2$ after integration	
A1	Correct integration, constant not needed	
A1	Use $x=0\quad v=3$ to obtain $c=9/2$	
M1	Substitute $v=0$ in their expression for v^2 or v. Award M0 if this expression includes t	
M1	Solve the resulting **3TQ** in x only, by any valid means. Must reach x = ...(less than 3 terms scores M0)	
A1cso	Correct value for x obtained from correct working. If x = -1 is seen it must be eliminated.	
	By definite integration:	
M1	For an equation of motion as above	
A1	Correct integration, ignore limits	
A1	Correct limits, as shown or both sets reversed	
M1	Substitute their limits, zeros need not be shown	
M1	Solve the resulting **3TQ** by any valid means. Must reach X = ...(less than 3 terms scores M0)	
A1cso	Correct value for x obtained from correct working.	
NB	**Solving a 3TQ,** **Calculator solutions:** Correct equation: correct answer implies correct method. (Incorrect answer M0) -1 need not be seen. Incorrect equation: No working, award M0 **By formula:** Correct general formula seen and used (even with incorrect sub) scores M1. With no general formula, award M1 if the sub in the formula is correct for their equation.	

Question Number	Scheme	Marks
2	R$(\uparrow)$ $T_A\cos 60° = T_B\cos 60° + mg$	M1A1
	$T_A = T_B + 2mg$	
	NL2 along radius: $T_A\cos 30° + T_B\cos 30° = ma\cos 30°\omega^2$	M1A1A1
	$T_A + T_B = ma\omega^2$	
	$T_A = \frac{1}{2}\left(ma\omega^2 + 2mg\right)$	dM1A1
	$T_B = \frac{1}{2}\left(ma\omega^2 - 2mg\right)$	A1
	$T_A = \frac{1}{2}\left(ma\omega^2 + 2mg\right) < 3mg$	
	$\omega^2 < \frac{4g}{a}$	M1
	$T_B = \frac{1}{2}\left(ma\omega^2 - 2mg\right) > 0$	
	$\omega^2 > \frac{2g}{a}$	M1
	$S = \frac{2\pi}{\omega} \Rightarrow \pi\sqrt{\frac{a}{g}} < S < \pi\sqrt{\frac{2a}{g}}$ $\quad k = 2$	dM1A1cso (12)
		[12]
M1	Resolving vertically. Both tensions resolved but can be sin or cos of 30 or 60. Omission of g is an accuracy error.	
A1	Fully correct equation	
M1	Attempt NL2 along the radius. Both tensions resolved but can be sin or cos of 30º or 60º. Acceleration in either form. Allow with r instead of $a\cos 30°$	
A1	Both forces correct. (r or $a\cos 30°$)	
A1	Fully correct equation with acceleration in $a\cos 30° \times \omega^2$ form	
dM1	Solve the equations for either tension in terms of m, a, ω (g may be missing). Depends on both M marks above.	
A1	Either tension correct	
A1	Second tension correct	
M1	Use their $T_A < 3mg$ to obtain an inequality for ω^2 $(\text{or } \omega)$ in terms of g and a Use of $\leqslant$ scores M0	
M1	Use their $T_B > 0$ to obtain an inequality for ω^2 $(\text{or } \omega)$ in terms of g and a Use of $\geqslant$ scores M0	
dM1	Use $S = \frac{2\pi}{\omega}$ with **both** inequalities to obtain a final result. Depends on the two M marks for the inequalities.	
A1cso	Correct final result as shown in the question from fully correct working. Value of k need not be shown explicitly.	

Question Number	Scheme	Marks
	Solutions using $\omega = \dfrac{2\pi}{S}$ $\left(\text{or } \dfrac{2\pi}{T}\right)$	
	$\text{R}(\uparrow)$ $T_A \cos 60° = T_B \cos 60° + mg$	M1A1
	$T_A = T_B + 2mg$	
	$T_A + T_B = ma\left(\dfrac{2\pi}{S}\right)^2$	M1A1A1
	$T_A = \dfrac{1}{2}\left(ma\left(\dfrac{2\pi}{S}\right)^2 + 2mg\right)$	dM1A1
	$T_B = \dfrac{1}{2}\left(ma\left(\dfrac{2\pi}{S}\right)^2 - 2mg\right)$	A1
	$T_A = \dfrac{1}{2}\left(ma\left(\dfrac{2\pi}{S}\right)^2 + 2mg\right) < 3mg$	
	$S^2 > \dfrac{\pi^2 a}{g}$	M1
	$T_B = \dfrac{1}{2}\left(ma\left(\dfrac{2\pi}{S}\right)^2 - 2mg\right) > 0$	
	$S^2 < \dfrac{\pi^2 a}{2g}$	M1
	$\Rightarrow \pi\sqrt{\dfrac{a}{g}} < S < \pi\sqrt{\dfrac{2a}{g}}$ $\quad k = 2$	dM1A1cso (12)
NB	The final M mark is for using $S = \dfrac{2\pi}{\omega}$ and must only be awarded when both inequalities have been used to obtain the final result. **Solutions using** T_A=3mg and $T_B = 0$: If **2 cases** are considered, (i) with T_A=3mg and (ii) with $T_B = 0$, first 8 marks are available but no more. If equations are formed including T_A=3mg and $T_B = 0$ **in the same equation**, there may be marks gained before the sub is made but once the sub is made there are no further marks available.	

Question Number	Scheme	Marks
3(a)	$v^2 = \omega^2\left(a^2 - \dfrac{a^2}{4}\right) = \dfrac{3a^2\omega^2}{4}$	
	$\dfrac{27a^2}{4} = \dfrac{3a^2\omega^2}{4}$	M1
	$\omega = 3$	A1
	Period = $\dfrac{2\pi}{3}$	A1ft (3)
(b)	Max mag of accel = $a\omega^2$	
	$45 = 9a$, $a = 5$	M1,A1ft (2)
(c)	$x = a\sin\omega t$ $\dot{x} = a\omega\cos\omega t$ (or $x = a\cos\omega t$ $\dot{x} = -a\omega\sin\omega t$)	
	$\dot{x}_{\max} = 5\times 3 = 15$ (m s^{-1})	M1A1ft (2)
	OR $v_{\max} = a\omega = 5\times 3 = 15$ (m s^{-1}) M1A1ft (2)	
(d)	Time A to C $\dfrac{1}{2}a = a\cos\omega t \Rightarrow \dfrac{1}{2} = \cos 3t$	
	$t_{AC} = \dfrac{1}{3}\cos^{-1}\left(\dfrac{1}{2}\right) = \dfrac{\pi}{9}$ $(0.3490...)$	M1A1
	Time A to D $\dfrac{\pi}{9} + \dfrac{2\pi}{12} = \dfrac{5\pi}{18}$	
	$x_D = 5\cos\left(3\times\dfrac{5\pi}{18}\right) = -\dfrac{5\sqrt{3}}{2}$ $(= -4.330)$	M1A1
	Distance CD $\dfrac{5}{2} + \dfrac{5\sqrt{3}}{2} = \dfrac{5}{2}\left(1+\sqrt{3}\right)$ or 6.8 (m) (or better)	A1ft (5)
		[12]

Question Number	Scheme	Marks
(a)		
M1	Use of $v^2 = \omega^2\left(a^2 - x^2\right)$ with $v = \frac{3a\sqrt{3}}{2}$, $x = \frac{1}{2}a$, amp $= a$ (or any other complete method)	
A1	Correct value for ω	
A1ft	Correct period, follow through their ω	
(b)		
M1	Use max mag of accel $= a\omega^2$ with their ω	
A1ft	$a = 5$	
(c)		
M1	Use either method shown with their values of a and ω to obtain a value for the max speed	
A1ft	$v_{\max} = 15 \ \left(\mathrm{m\,s^{-1}}\right)$	
(d)		
M1	Attempt time A to C with their value of ω and $x = \frac{1}{2}a$ or half their amp. Must reach a value for t using radians	
A1	Correct time, exact or min 3 sf (no penalty for using an incorrect amp) The above 2 marks can be awarded for a time even if no indication of which time the are finding (ie not stated to be time from end to C or centre to C. Following marks can only be awarded if work is consistent with their work for these 2 marks.	
M1	Add ¼ period and use this time to obtain a value for x at D using their value for a or just a	
A1	Correct value of x exact or min 3 sf or a multiple of a	
A1ft	Correct distance CD, follow through their x_D Must be positive Min 2 sf for decimal	
ALT (d)	Time C to centre O $\quad \frac{1}{2}a = a\sin\omega t \Rightarrow \frac{1}{2} = \sin 3t$	
	$t_{CO} = \frac{1}{3}\sin^{-1}\left(\frac{1}{2}\right) = \frac{\pi}{18} \quad (0.1745...)$	M1A1
	Time O to D $\quad \frac{\pi}{6} - \frac{\pi}{18} = \frac{\pi}{9}$	
	$OD = a\sin\frac{\pi}{3} = \frac{\sqrt{3}}{2}a$	M1A1
	Distance CD $\frac{5}{2} + \frac{5\sqrt{3}}{2} = \frac{5}{2}\left(1+\sqrt{3}\right)$ or 6.83 (m)	A1ft

Question Number	Scheme	Marks
4(a)		
	R$\left(\uparrow\right)$: $2T\cos\theta = 2mg$	M1A1
	$\cos\theta = \dfrac{3}{5}$ (or other correct trig function)	B1
	$T = \dfrac{\lambda \times l}{4l}$ or $\dfrac{\lambda \times 0.5l}{2l}$	M1A1
	$T = \dfrac{5mg}{3} = \dfrac{\lambda}{4}$	
	$\lambda = \dfrac{20}{3}mg$ *	M1A1cso (7)
(b)	Dist below $AB = l\sqrt{3^2 - 2^2} = l\sqrt{5}$ $\left(\text{or } 2.23l\right)$	B1
	EPE at start: $= \dfrac{\lambda \times (2l)^2}{2 \times 4l} = \dfrac{20mg}{3} \times \dfrac{(2l)^2}{8l}$ $\left(= \dfrac{10mgl}{3}\right)$	M1A1
	GPE gained if P reaches $AB = 2mgl\sqrt{5} = 4.47...mgl$	B1
	$\dfrac{10}{3} < 4.47...$	M1
	$\therefore$ P cannot reach the line AB	A1cso (6)
		[13]

Question Number	Scheme	Marks
(a)M1	Resolve vertically. Must have 2 tensions, both resolved and (2)m or (2)mg not resolved	
A1	Fully correct equation	
B1	Correct sine, cosine or tangent, seen explicitly or used in an equation	
M1	Use Hooke's law for the full string or half string with their attempt at the extension	
A1	Fully correct equation	
M1	Eliminate T between their 2 equations to obtain an expression for λ	
A1cso	Correct **given** result obtained from correct working	
(b)		
B1	Correct initial distance below the level of AB	
M1	Calculate the initial EPE, formula to be of the form $\frac{\lambda x^2}{k \times \text{natural length}}$, $k = 2$ or 1. Must use the full string or 2 x half strings	
A1	Correct initial EPE Need not be simplified	
B1	GPE gained if P reaches AB	
M1	Compare the initial EPE with the GPE – using exact or decimal results	
A1cso	Correct work and a conclusion (exact or decimals results used)	
	Alternatives for last 3 marks:	
ALT1	Assume P stops at distance x below AB	
B1	GPE gained $2mg\left(l\sqrt{5} - x\right)$	
M1	Attempt an energy equation with initial and final KE zero **and** show it has a positive, real root $\frac{10mgl}{3} - 2 \times \frac{20mg}{3} \times \frac{\left(\sqrt{4l^2 + x^2} - 2l\right)^2}{4l} = 2mg\left(l\sqrt{5} - x\right)$ Final KE must be 0, 2 EPE terms needed	
A1cso	Correct work and a conclusion	
ALT 2	Assume final extension is x Similar work may be seen with final extension $2x$	
B1	GPE gained $2mg\left(l\sqrt{5} - \sqrt{\left(2l + \frac{x}{2}\right)^2 - 4l^2}\right)$	
M1	Attempt an energy equation with initial KE zero **and** show it has a positive, real root $\frac{10mgl}{3} - \frac{20mg}{3} \times \frac{x^2}{4l} = 2mg\left(l\sqrt{5} - \sqrt{\left(2l + \frac{x}{2}\right)^2 - 4l^2}\right)$ Final KE must be 0, 2 EPE terms needed	
A1cso	Correct work and a conclusion	

Question Number	Scheme	Marks
ALT3	Assume P stops after rising a distance x	
B1	GPE gained $2mgx$	
M1	Attempt an energy equation with initial and final KE zero **and** show it has a positive, real root	
	$\frac{10mgl}{3} - 2\times\frac{20mg}{3}\times\frac{\left(\sqrt{4l^2+\left(l\sqrt{5}-x\right)^2}-2l\right)^2}{4l} = 2mgx$	
	Final KE must be 0, 2 EPE terms needed	
A1cso	Correct work and a conclusion	
	Alternative for last 2 marks:	
M1	Attempt an energy equation including the KE at level of AB and solve for v^2	
A1cso	$v^2 < 0$ so P cannot reach the level of AB (Equation must be correct)	
	Warning: in (b), use of HL with extension $2l$ can also lead to the "correct" result, but scores M0 as it is not an energy solution. (May possibly gain the B marks but this is unlikely.)	

Question Number	Scheme	Marks
5(a)	$\text{Vol} = (\pi)\int_{\frac{3}{5}r}^{r}\left(r^2 - x^2\right)\mathrm{d}x = (\pi)\left[r^2x - \frac{1}{3}x^3\right]_{\frac{3}{5}r}^{r}$	M1A1
	$= (\pi)\left(r^3 - \frac{1}{3}r^3 - \left(\frac{3}{5}r^3 - \frac{9}{125}r^3\right)\right) \quad \left(= \frac{52}{375}(\pi)r^3\right)$	M1
	$(\pi)\int_{\frac{3}{5}r}^{r} x\left(r^2 - x^2\right)\mathrm{d}x = (\pi)\left[\frac{1}{2}r^2x^2 - \frac{1}{4}x^4\right]_{\frac{3}{5}r}^{r}$	M1A1
	$= (\pi)\left(\frac{1}{2}r^4 - \frac{1}{4}r^4 - \left(\frac{9}{50}r^4 - \frac{81}{2500}r^4\right)\right) \quad \left(= \frac{64}{625}(\pi)r^4\right)$	M1
	$\bar{x} = \frac{\int xy^2\mathrm{d}x}{\int y^2\mathrm{d}x} = \frac{\frac{64}{625}}{\frac{52}{375}}r$	M1
	$= \frac{48}{65}r$ *	A1cso (8)
(b)	Bowl alone: Mass ratio 6^3 5^3 91	
	Dist from A: $\frac{3}{8}\times 6$ $\frac{3}{8}\times 5$ $\bar{y}$	
	$216\times\frac{3}{8}\times 6 - 125\times\frac{3}{8}\times 5 = 91\bar{y}$	M1A1A1
	$\bar{y} = 2.7651...$ $\left(\frac{2013}{728}, \ 2\frac{557}{728}\right)$	A1
	Bowl and liquid: Mass ratio 5 2 7	
	Dist from A: 2.7651... $\frac{48}{13}$ $\bar{z}$	B1 (48/13)
	$7\bar{z} = 5\times 2.7651 + \frac{48}{13}\times 2$	M1A1ft
	$\bar{z} = 3.030... = 3.03$ cm	A1 (8) **[16]**
ALT	Find mass of whole hemisphere and part cut away in terms of M and use a single moments equation (see end)	

Question Number	Scheme	Marks
(a)	**Lamina scores 0/8.** **If no evidence of algebraic integration seen, only the last M mark is available.**	
M1	Attempt the volume integral, π and limits not needed (ignore any shown)	
A1	Correct integration, π and limits not needed (ignore any shown)	
dM1	Substitute the correct limits in their result. Evidence of substitution must be seen. Depends on previous M mark	
M1	Attempt $\int xy^2\,\mathrm{d}x$, π and limits not needed (ignore any shown)	
A1	Correct integration, π and limits not needed (ignore any shown)	
dM1	Substitute the correct limits in their result. Evidence of substitution must be seen. Depends on previous M mark	
M1	Use $\bar{x} = \dfrac{\int xy^2\mathrm{d}x}{\int y^2\mathrm{d}x}$ with their previous results (need not be simplified results). π in both or neither integral	
A1cso	Correct final (**given)** result obtained from fully correct working.	
(b)		
M1	Attempt a moments equation with the *difference* of two hemispheres. Dimensions for the hemispheres must be correct.	
A1	Correct masses or ratio of masses	
A1	Correct distances	
A1	Correct distance for the bowl – exact or decimal	
B1	For the correct distance of the c of m of the liquid from A	
M1	Attempt a moments equation – bowl and liquid added. Must attempt the distance for the liquid ie we are looking for a numerical distance , not just a letter and must have shown evidence of calculating the c of m of the bowl (M mark for this may have been lost)	
A1ft	Correct equation, follow through their distances (ie 48/13 and c of m of bowl)	
A1	Correct answer from correct working. Must be 3 sf	

Question Number	Scheme	Marks
ALT (b)	Vol of bowl $=\frac{2}{3}\pi\left(6^3-5^3\right)=\frac{2}{3}\pi\times 91$	
	$\frac{2}{3}\pi\rho\times 91=5M$	B1
	Mass ratio $\quad 6^3 \qquad\qquad 5^3$	
	$6^3\times\frac{5}{91}M \qquad 5^3\times\frac{5}{91}M \qquad 2M \qquad 7M$	M1A1A1
	Dist from A: $\frac{3}{8}\times 6 \qquad \frac{3}{8}\times 5 \qquad \frac{48}{13} \qquad \bar{y}$	B1(48/13)
	$6^3\times\frac{5}{91}M\times\frac{3}{8}\times 6-5^3\times\frac{5}{91}M\times\frac{3}{8}\times 5+2M\times\frac{48}{13}=7M\,\bar{y}$	M1A1ft
	$\bar{y}=3.030...=3.03$	A1 (8)

B1	For a correct equation connecting the mass of the bowl and $5M$. Award if $\frac{5}{91}M$ or $\frac{5}{91}$ is seen used correctly in at least one term in their equation. Enter as the first A mark on e-PEN
M1	For attempting the mass ratio for the 4 parts needed including their "5/91"
A1A1	Deduct one per error
B1	For 48/13
M1	Attempt a moments equation with 4 terms and correct signs. An attempt at the mass ratio of the parts based on the mass of the bowl being 5M must have been seen even if this attempt failed to qualify for the first M mark.
A1ft	Correct equation, follow through their masses and distances (ie 48/13 and c of m of bowl)
A1	Correct answer from correct working. Must be 3 sf

Question Number	Scheme	Marks
6(a)	Energy to B: $\frac{1}{2}m\times\frac{7ag}{2}-\frac{1}{2}mv^2=mga$	M1A1
	NL2 along rad at B: $R=m\frac{v^2}{a}$	M1A1
	$R=\frac{3mg}{2}$	A1cao (5)
(b)	Energy A to C: $\frac{1}{2}m\times\frac{7ag}{2}-\frac{1}{2}mV^2=mga\left(1+\cos\theta\right)$ OR energy B to C: $\frac{1}{2}m\times\frac{3ag}{2}-\frac{1}{2}mV^2=mga\cos\theta$	M1A1
	NL2 along rad at C: $mg\cos\theta=m\frac{V^2}{a}$	M1A1
	Solve for θ: $\frac{1}{2}m\times\frac{7ag}{2}-\frac{1}{2}mga\cos\theta=mga\left(1+\cos\theta\right)$	dM1
	$\cos\theta=\frac{1}{2}$ $\quad\left(\theta=60^\circ\right)$	A1
	Horiz motion: $s=a\sin\theta$, speed $=V\cos\theta$	
	$t=\frac{a\sin\theta}{V\cos\theta}=\sqrt{\frac{2}{ag}}\times a\sqrt{3}=\sqrt{\frac{6a}{g}}$	M1
	Vert motion: $s=-V\sin\theta\times t+\frac{1}{2}gt^2$	M1
	$s=-\sqrt{\frac{ag}{2}}\times\frac{\sqrt{3}}{2}\times\sqrt{\frac{6a}{g}}+\frac{1}{2}g\times\frac{6a}{g},\ =-\frac{3a}{2}+3a=\frac{3a}{2}$	A1,A1
	(Horiz dist A to C: $s=a\sin60^\circ=\frac{a\sqrt{3}}{2}$ sufficient that this was used to find the time)	
	Vert dist A to C: $s=\frac{3a}{2}$	
	$\therefore$ Strikes surface at A	A1cso (11) [16]

Question Number	Scheme	Marks
(a)M1	Attempt an energy equation from start to *B*. Must have 2 KE terms and one PE term	
A1	Fully correct equation	
M1	Attempt an equation of motion along the radius at *B*. Acceleration can be in either form. Only force to be the reaction.	
A1	Fully correct equation, acceleration as shown.	
A1cao	Eliminate v^2 to obtain the expression for the reaction at *B*.	
(b)		
M1	Attempt an energy equation from start to *C*. Must have 2 KE terms and a PE term which includes a trig function. PE may be expressed as 2 separate terms	
A1	Fully correct equation	
M1	Attempt an equation of motion along the radius at *C*. The reaction may be included initially but must become 0 before this mark can be awarded. Weight must be resolved; acceleration can be in either form.	
A1	Fully correct equation, acceleration as shown.	
dM1	Eliminate *V* and obtain a value for $\cos\theta$. Depends on the 2 previous M marks of (b)	
A1	Correct value for $\cos\theta$. Award if seen explicitly or implied by subsequent working.	
M1	Use the horizontal motion to obtain the time to travel a horizontal distance $= a\sin\theta$, with their θ. Speed must be resolved. Time obtained must be a function of *a* and *g* only.	
M1	Use $s = ut + \frac{1}{2}at^2$ to obtain an expression for the vertical distance at time *t*. Acceleration to be *g* and initial speed to be a component of their *V*. (trig function or its value allowed here)	
A1	Correct equation in *a*, *g* and *s*	
A1	Correct vertical distance	
A1cso	State that or use the horizontal distance *A* to *C* is $a\sin 60° = \frac{a\sqrt{3}}{2}$ and the vertical distance *A* to *C* is $(3a)/2$ so the particle strikes the surface at *A*. All work must be correct.	
ALT	**For the last 4 marks:** Find time to travel 3*a*/2 vertically down from *C*:	
	Vert motion: $s = -V\sin\theta \times t + \frac{1}{2}gt^2$	M1
	$\frac{3a}{2} = -\sqrt{\frac{ag}{2}} \times \frac{\sqrt{3}}{2}t + \frac{1}{2}gt^2, \Rightarrow t = \sqrt{\frac{6a}{g}}$	A1,A1
	Same time horiz and vertically so strikes surface at *A*	A1cso
M1	Use $s = ut + \frac{1}{2}at^2$ to obtain an expression for the time to travel $\frac{3a}{2}$ vertically. Acceleration to be *g* and initial speed to be a component of their *V*. (trig function or its value allowed here)	
A1	Correct equation in *a*, *g* and *t*	
A1	$t = \sqrt{\frac{6a}{g}}$	
A1cso	State that the horizontal and vertical times are the same, so the particle strikes the surface at *A*. All work must be correct.	
NB	θ is defined in the question as the angle with the vertical. If the angle with the horiz is called θ but otherwise *totally* correct, deduct A mark for $\cos\theta$ and the final a mark. If there are errors in the working, mark as scheme.	

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