Mark Scheme (Results)

Summer 2018

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

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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.

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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:

<u>'M' marks</u>
These are marks given for a correct method or an attempt at a correct method. In Mechanics they are usually awarded for the application of some mechanical principle to produce an equation.
e.g. resolving in a particular direction, taking moments about a point, applying a suvat equation, applying the conservation of momentum principle etc.
The following criteria are usually applied to the equation.

To earn the M mark, the equation
(i) should have the correct number of terms
(ii) be dimensionally correct i.e. all the terms need to be dimensionally correct
e.g. in a moments equation, every term must be a 'force x distance' term or 'mass x distance', if we allow them to cancel 'g' s.
For a resolution, all terms that need to be resolved (multiplied by sin or cos) must be resolved to earn the M mark.

M marks are sometimes dependent (DM) on previous M marks having been earned.
e.g. when two simultaneous equations have been set up by, for example, resolving in two directions and there is then an M mark for solving the equations to find a particular quantity – this M mark is often dependent on the two previous M marks having been earned.

<u>'A' marks</u>
These are dependent accuracy (or sometimes answer) marks and can only be awarded if the previous M mark has been earned. E.g. M0 A1 is impossible.

<u>'B' marks</u>
These are independent accuracy marks where there is no method (e.g. often given for a comment or for a graph)

A few of the A and B marks may be f.t. – follow through – marks.

3. General 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)
- dep – dependent
- indep – independent
- dp decimal places
- sf significant figures
- * The answer is printed on the paper
- $\lfloor$ 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.

June 2018
WME03 M3
Mark Scheme

Question Number	Scheme	Marks
1.	$T = \dfrac{29.4(0.5-l)}{l}$ $1.5g = \dfrac{29.4(0.5-l)}{l}$ $1.5 = \dfrac{1.5-3l}{l}$ $3l = 1 \quad l = 0.33$ or $0.333\,\text{m}$ must be 2 or 3 sf	M1A1 dM1A1 [4]
M1 **A1** **dM1** **A1** **NB:**	Attempt Hooke's Law with one unknown (natural length or extension but not both) Extension = 0.5 scores M0. T or 1.5 for this mark Fully correct vertical equation Solve their equation depends on the first M mark Correct natural length Ignore $l = \frac{1}{3}$ if 0.33 or 0.33 also seen If extension is used as the unknown and work not completed to give the natural length, first M1A1 only available.	

Question Number	Scheme	Marks
2(a)	$\ddot{x} = -\omega^2 x$	
	$\omega^2 = \dfrac{0.5}{0.02}, \Rightarrow \omega = 5$	M1,A1
	Period $= \dfrac{2\pi}{5}$ s Accept 1.3, 1.26 or better	M1A1 (4)
(b)	$v^2 = \omega^2\left(a^2 - x^2\right)$	
	$0.3^2 = \dfrac{0.5}{0.02}\left(a^2 - 0.02^2\right)$	M1A1ft
	$a = 0.06324...$ Accept 0.063 or better $\left(\text{exact is } \dfrac{\sqrt{10}}{50} \text{ oe}\right)$	A1 (3)
(c)	$\dfrac{1}{2}a = a\sin\omega t$	
	$t = \dfrac{1}{\omega}\sin^{-1}\left(\dfrac{1}{2}\right), = \dfrac{\pi}{30} \quad (= 0.104...)$	M1,A1
	Total time $= 4\times\dfrac{\pi}{30}, = \dfrac{2\pi}{15}$ s Accept 0.42, 0.419 or better	dM1,A1 (4)
		[11]
(a)		
M1	Use $\ddot{x}$ or $a = -\omega^2 x$ with $\ddot{x} = 0.5$ and $x = 0.02$ to form an equation for ω^2. Allow equation with or without a minus sign.	
A1	Obtain correct value for ω or ω^2 from correct working ie no sign errors ($\omega^2 = -25, \omega = 5$ scores M1A0)	
M1	Use period $\dfrac{2\pi}{\omega}$ with their ω	
A1	Correct period, exact or decimal (can score M1A0M1A1 in (a))	
(b)		
M1	Use $v^2 = \omega^2\left(a^2 - x^2\right)$ with $v = 0.3, x = 0.02$ and their ω	
A1ft	Correct equation, follow through their ω	
A1	Correct value of *a*, 2 sf or better (inc exact)	
(c)		
M1	Use $x = a\sin\omega t$ or $x = a\cos\omega t$ with their ω and $x = \pm\dfrac{1}{2}a$. May use their value for *a* or use *a*	
A1	Obtain the correct time from the centre or end of oscillation (depends on the equation used)	
dM1	Correct method to complete to obtain the required time. Depends on the first M mark of (c). If $x = a\cos\omega t$ is used this mark needs "period $-4\times$ time found" (or any equivalent to that)	
A1	Correct total time, exact or decimal	

Question Number	Scheme	Marks
3 (a)	$\cos A = \sin B = \frac{4}{5},\ \sin A = \cos B = \frac{3}{5}$	B1 any of these
	$T_A \cos A = T_B \cos B + mg$	M1A1
	$T_A \sin A + T_B \sin B = mr\omega^2, = 4l \sin A \times m\omega^2 \quad \left(= \frac{12}{5} ml\omega^2\right)$	M1A1,A1
	$\frac{4}{5} T_A = \frac{3}{5} T_B + mg$	
	$\frac{3}{5} T_A + \frac{4}{5} T_B = 4lm\omega^2 \times \frac{3}{5}$	
(i)	$T_A = \frac{m}{25}\left(36l\omega^2 + 20g\right)$ oe	dM1 (either) A1
(ii)	$T_B = \frac{m}{25}\left(48l\omega^2 - 15g\right)$ oe	A1 (9)
(b)	$T_B \geqslant 0 \Rightarrow 48l\omega^2 \geqslant 15g$	M1
	$\omega \geqslant \sqrt{\frac{15g}{48l}} = \frac{1}{4}\sqrt{\frac{5g}{l}}$	
	$R \leqslant 2\pi \times 4\sqrt{\frac{l}{5g}}$	dM1
	(least) $k = 8$	A1 cso (3) **[12]**
(a)B1	Any correct sine or cosine seen explicitly or used.	
M1	Resolve vertically	
A1	Correct equation, can have trig functions (as shown) or numerical values for these	
M1	Equation of motion along the radius, acceleration in either form, r for radius accepted here	
A1	Left hand side correct, trig functions or numerical values accepted	
A1	Correct right hand side. Acceleration to be $r\omega^2$ with radius $4l \sin A$ or $\frac{12}{5}$	
(i)dM1	Solve their 2 equations to obtain an expression for either tension Depends on both previous M marks	
A1	Correct expression for T_A, any equivalent form	
(ii)A1	Correct expression for T_B, any equivalent form	
NB	Ignore (i) (ii) labels provided it is clear which is the tension in AC and which is the tension in BC	
(b)		
M1	Use $T_B \geqslant 0$ to obtain an inequality for ω^2. Must use $\geqslant$	
dM1	Use $R = \frac{2\pi}{\omega}$ with their inequality for ω^2 to obtain an inequality for R. Allow use of T instead of R.	
A1cso	Deduce the correct value for k . The value must be shown explicitly but need not include "least". (no inequality allowed)	

Question Number	Scheme	Marks
4	$0.5u = 1.5 \quad u = 3\text{ m s}^{-1}$	B1
	Work done against friction $= 0.7 \times 0.5\cos 30g \times 0.6$	M1A1
	Initial EPE $= \dfrac{\lambda \times 0.6^2}{2 \times 0.6}\left(= \dfrac{0.6\lambda}{2} = 0.3\lambda\right)$	B1
	$\dfrac{\lambda \times 0.6^2}{2 \times 0.6} + \dfrac{1}{2} \times 0.5 \times 9 = 0.7 \times 0.5\cos 30g \times 0.6 + 0.5 \times g \times 0.6\sin 30$	M1A1A1 Ft EPE and Work
	$\lambda = 3.340... = 3.3$ or 3.34	A1 [8]

B1	Correct value for u, seen explicitly or used.
M1	Attempt the work done against friction. Weight must be resolved (sin/cos interchange accepted.) Distance moved to be 0.6 m. Mass can be 0.5 or m
A1	Correct work done. Mass can be 0.5 or m Allow both of the above marks if the work done against friction is embedded in some incorrect work eg including other forces to form a resultant force.
B1	Correct initial EPE Need not be simplified. The work done and the EPE may not be shown explicitly. Check the equation if necessary.
M1	Attempt a complete work-energy equation. Must have an EPE, a GPE, a KE and a (dimensionally correct) work against friction term. The final KE may be included provided it becomes 0 here or later. EPE term must be of the form $\dfrac{k\lambda x^2}{l}$ $k = \dfrac{1}{2}$, 1 or 2
A1ft **A1ft**	Deduct one per error. Follow through their EPE and work.
A1	Correct value of λ, 2 or 3 sf only.

1

Question Number	Scheme	Marks
5(a)	$0.8v\dfrac{\mathrm{d}v}{\mathrm{d}x}=\dfrac{4}{(x+1)^3}$	M1A1
	$v\dfrac{\mathrm{d}v}{\mathrm{d}x}=\dfrac{5}{(x+1)^3}$	
	$\dfrac{1}{2}v^2=-\dfrac{5}{2(x+1)^2}\ (+c)$	dM1A1
	$(t=0,v=0,x=0)\ \Rightarrow c=\dfrac{5}{2}$	ddM1
	$v^2=5\left(1-\dfrac{1}{(x+1)^2}\right)=5\left(\dfrac{(x+1)^2-1}{(x+1)^2}\right)$ *	A1cso (6)
(b)	$v=\dfrac{\mathrm{d}x}{\mathrm{d}t}=\sqrt{5\left(\dfrac{(x+1)^2-1}{(x+1)^2}\right)}$	M1
	$\displaystyle\int\dfrac{(x+1)}{\sqrt{(x+1)^2-1}}\mathrm{d}x=\int\sqrt{5}\,\mathrm{d}t$	M1A1
	$\left((x+1)^2-1\right)^{\frac{1}{2}}=\sqrt{5}t\ (+k)$	M1A1
	$t=0,x=0\ \Rightarrow k=0$	
	$(x+1)^2-1=5t^2\qquad x=\sqrt{5t^2+1}-1$	
	Dist $=\sqrt{81}-1-\left(\sqrt{21}-1\right)=9-\sqrt{21}$ or 4.417 m (accept 4.4 or better)	M1A1cso(7) **[13]**
(a)M1	Attempt an equation of motion with acceleration $=v\dfrac{\mathrm{d}v}{\mathrm{d}x}$. Can be implied by subsequent work.	
A1	Fully correct equation. Can be implied by subsequent work.	
dM1	Attempt the necessary integration. $\dfrac{k}{(x+1)^3}\rightarrow\pm\dfrac{k'}{(x+1)^2}$ Depends on the first M mark	
A1	Correct integration (not ft). Constant may be omitted.	
ddM1	Use the given initial conditions to obtain a value for the constant. Depends on both preceding M marks. Initial conditions need not be shown explicitly.	
A1cso	Reach the **given** answer in the form shown in the question. No errors in the work.	

Question Number	Scheme	Marks
(b)M1 **M1** **A1** **M1** **A1** **M1** **A1cso**	Replace v with dx/dt in either the answer in (a) (with or without taking square root first) or in an equivalent expression drawn from their working in (a) Separate the variables ready to integrate. Must reach an integrand which can be integrated. All correct so far Attempt the integration by any valid means (eg inspection or substitution). Must include $\dfrac{(x+1)}{\sqrt{(x+1)^2-1}} \to A\left((x+1)^2-1\right)^{\frac{1}{2}}$ or $\dfrac{(x+1)}{\sqrt{x^2+2x}} \to B\left(x^2+2x\right)^{\frac{1}{2}}$ oe Correct integration (not ft). Constant may be omitted. Use the given values of t to obtain the distances OA and OB and hence the distance AB. The function must have been integrated but third M mark may have been lost. Correct distance. Exact or decimal accepted. Constant must have been included and shown to be 0.	
(a)	By definite integration: $0.8v\dfrac{\mathrm{d}v}{\mathrm{d}x} = \dfrac{4}{(x+1)^3}$	M1A1
	$\int_0^v v\,\mathrm{d}v = \int_0^x \dfrac{5}{(x+1)^3}\,\mathrm{d}x$	
	$\left[\dfrac{1}{2}v^2\right]_0^v = \left[-\dfrac{5}{2(x+1)^2}\right]_0^x$ (Integration condition as main scheme)	dM1A1 Ignore limits
	$\dfrac{1}{2}v^2 = -\dfrac{5}{2(x+1)^2} + \dfrac{5}{2}$	ddM1 Sub correct limits
	$v^2 = 5\left(1 - \dfrac{1}{(x+1)^2}\right) = 5\left(\dfrac{(x+1)^2-1}{(x+1)^2}\right)$	A1cso (6)
(b)	Complete solution following definite integration requires distances O to A and O to B being found followed by finding their difference. $v = \dfrac{\mathrm{d}x}{\mathrm{d}t} = \sqrt{5\left(\dfrac{(x+1)^2-1}{(x+1)^2}\right)}$	M1
	$\int_0^X \dfrac{(x+1)}{\sqrt{(x+1)^2-1}}\,\mathrm{d}x = \int_0^T \sqrt{5}\,\mathrm{d}t$	M1A1 ignore limits
	$\left[\left((x+1)^2-1\right)^{\frac{1}{2}}\right]_0^X = \left[\sqrt{5}t\right]_0^T$	M1A1 Integration only. Ignore limits
	$(X+1)^2 - 1 = 5T^2 \quad X = \sqrt{5T^2+1} - 1$	
	Dist $= \sqrt{81} - 1 - \left(\sqrt{21} - 1\right) = 9 - \sqrt{21}$ or 4.417 m (accept 4.4 or better)	M1A1 Correct completion

Question Number	Scheme	Marks
6(a)	$(\pi)\int y^2x\,\mathrm{d}x=(\pi)\int_0^h\left(\frac{r}{h}\right)^2x^3\mathrm{d}x$ OR $(\pi)\int y^2x\,\mathrm{d}x=(\pi)\int_0^h\left(r-\frac{r}{h}x\right)^2x\,\mathrm{d}x$	M1
	$=(\pi)\left(\frac{r}{h}\right)^2\left[\frac{x^4}{4}\right]_0^h,\ =(\pi)\frac{r^2h^4}{4h^2}\ \left(=(\pi)\frac{r^2h^2}{4}\right)$	dM1,A1
	$\bar{x}=(\pi)\frac{r^2h^2}{4}\div\frac{1}{3}(\pi)r^2h=\frac{3}{4}h$ *	M1A1cso (5)
(b)	cone: Mass $5m$, Distance from O $\frac{1}{4}\times 6r$; hemisphere: Mass km, Distance from O $(-)\frac{3}{8}r$; S: Mass $m(5+k)$, Distance from O $\bar{x}$	B1
	$5m\times\frac{3}{2}r-km\times\frac{3}{8}r=m(5+k)\bar{x}$	M1A1ft
	$\bar{x}=\frac{3r(20-k)}{8(5+k)}$	A1 (4)
(c)	Angle between AO and vertical = 30° or angle between axis and vertical = 60°	B1
	$\tan 30=\frac{\bar{x}}{r},\ =\frac{3(20-k)}{8(5+k)}$ OR $\tan 60=\frac{r}{\bar{x}},\ =\frac{8(5+k)}{3(20-k)}$	M1,A1ft
	$k=4.844...=5$	A1cso (4) **[13]**
(a) **M1**	Use $(\pi)\int y^2x\,\mathrm{d}x$ to obtain an integral in x. Integral should be one of the forms shown. π and limits need not be shown	
dM1	Attempt the integration; π and limits need not be shown. Depends on the previous M mark.	
A1	Substitute (correct) limits to obtain correct result. π not needed, no need to simplify. Second integral gives $\frac{r^2h^2}{12}$ or $\left(\frac{1}{2}-\frac{2}{3}+\frac{1}{4}\right)r^2h^2$ on substitution of limits	
M1	Divide their result by the volume (given formula or an integral), π to be included in numerator and denominator or in neither. Can have the distance from the vertex or the distance from the base. Must reach $\bar{x}=...$	
A1cso	Correct **given** result; no errors in the working. If the distance from the base has been found $h-\frac{1}{4}h$ must be seen to justify the answer. **Special Case:** Cone base radius r and height $6r$ Equation is $y=\frac{1}{6}x$ Integral is $(\pi)\int_0^{6r}\frac{x^3}{36}\mathrm{d}x$ or $(\pi)\int_0^{6r}\left(r-\frac{x}{6}\right)^2x\,\mathrm{d}x$ Award M marks only (if earned)	

Question Number	Scheme	Marks
(b)		
B1	Correct distances shown explicitly or used. Negative sign may be missing here.	
M1	Moments equation including a minus sign. Must use the given masses (or ratio of them), not volumes.	
A1ft	Fully correct equation follow through their distances	
A1	Correct expression for the required distance. Must be positive but can include modulus sign. $(k-20)$ in the numerator without modulus signs scores A0. Equivalents accepted but not fractions within fractions.	
(c)		
B1	For either of the angles, shown explicitly or used. May be seen on a diagram.	
M1	$\tan 30 \text{ or } 60 = \frac{\bar{x}}{r} \text{ or } \frac{r}{\bar{x}}$ (ie 30 or 60 and fraction either way up)	
A1ft	Fully correct equation. Follow through their $\bar{x}$	
A1cso	$k = 5$	

Question Number	Scheme	Marks
7 (a)	$\frac{1}{2}mv^2 - \frac{1}{2}mu^2 = mgr(1-\cos\alpha)$	M1A1A1
	$mg\cos\alpha \ \ (-R) = m\frac{v^2}{r}$	M1A1
	$gr\cos\alpha = u^2 + 2gr(1-\cos\alpha)$	dM1
	$\cos\alpha = \frac{1}{3gr}(u^2+2gr)$ *	A1 cso (7)
(b)	At top $mg - R_{top} = \frac{mu^2}{r}$	
	For circular motion, $R_{top} > 0 \ \therefore \frac{u^2}{r} < g, \ u < \sqrt{gr}$ *	M1,A1cso (2)
ALT:	$\cos\alpha < 1 \quad u^2 + 2gr < 3gr, \quad u < \sqrt{gr}$	M1,A1cso (2)
(c)	$\frac{1}{2}m\times\frac{9}{2}gr - \frac{1}{2}mu^2 = 2mgr$	M1A1 A1
	$u^2 = \frac{1}{2}gr$	
	$\cos\alpha = \frac{1}{3gr}\left(\frac{1}{2}gr + 2gr\right)$	
	$\cos\alpha = \frac{5}{6}$	dM1A1cao (5) **[14]**

(a)	
M1	Energy equation with a difference of KE terms and one PE term or a difference of PE terms, m in all terms or none but must be clear it is an energy equation and not $v^2 = u^2 + 2as$
A1A1	-1 each error
M1	Attempt an equation of motion along the radius at *A*. *R* need not be included. Weight must be resolved, acceleration in either form. Accept $v^2 = rg\cos\alpha$
A1	Correct equation with or without *R*. Acceleration in form shown
dM1	Eliminate *v* between the two equations (and set *R* = 0 if *R* was included) Depends on both previous M marks.
A1cso	Correct **given** result (in the form shown) with no errors in the working. At least one intermediate step between $gr\cos\alpha = u^2 + 2gr(1-\cos\alpha)$ and the answer must be shown.
(b)	
M1	Attempt an equation of motion along the radius at the top and use $R_{top} > 0$ to obtain an inequality for u^2 Must use >
A1cso	Correct **given** result
ALT	**M1** Use $\cos\alpha < 1$ in the result from (a) to obtain an inequality for u^2 **A1cso** As above

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Question Number	Scheme	Marks
(c) **M1** **A1 A1** **dM1** **A1cao**	Energy equation from top to reaching the plane. Difference of KE terms and a PE term needed m in all terms or none (see (a)) -1 each error Use their expression for u^2 in the result given in (a) to obtain a numerical value for $\cos\alpha$ Complete to 5/6. Accept 0.83 or better.	
ALT 1 **M1** **A1A1** **M1** **A1cao**	**Alternatives for (c)** Use energy from A to the plane $\frac{1}{2}m\times\frac{9}{2}gr-\frac{1}{2}mv^2=mgr\left(1+\cos\alpha\right)$ M1 equation with correct no of terms and dimensionally correct A1A1 -1 each error Use their equation of motion from (a) to find an expression for v^2 and complete to a numerical value for $\cos\alpha$ Complete to 5/6. Accept 0.83 or better.	
ALT 2	Using SUVAT equations: Let speed at A be v_A where $v_A{}^2=u^2+2gr\left(1-\cos\alpha\right)$ (from the energy equation in (a)) Horiz comp = $v_A\cos\alpha$ Vert comp = $v_A\sin\alpha$ Vert comp at the plane $=V$ where $V^2=\left(v_A\sin\alpha\right)^2+2gr\left(1+\cos\alpha\right)$ $\left(\text{speed at plane}\right)^2=V^2+\left(v_A\cos\alpha\right)^2$ $=\left(v_A\sin\alpha\right)^2+2gr\left(1+\cos\alpha\right)+\left(v_A\cos\alpha\right)^2$ $\frac{9gr}{2}=v_A{}^2+2gr\left(1+\cos\alpha\right)$ $\frac{9gr}{2}=u^2+2gr\left(1-\cos\alpha\right)+2gr\left(1+\cos\alpha\right)$ $\frac{9gr}{2}=u^2+4gr\Rightarrow u^2=\frac{1}{2}gr$ $\cos\alpha=\frac{1}{3gr}\left(\frac{1}{2}gr+2gr\right)\Rightarrow\cos\alpha=\frac{5}{6}$	 M1A1A1 M1A1cao
   M1 **A1A1** **M1** **A1cao**	Find the speed at A, obtain horizontal and vertical components of this speed. Obtain the vertical component of the speed at the plane using SUVAT Obtain the resultant speed at the plane, equate to $3\sqrt{\frac{gr}{2}}$ and eliminate v_A. For the equation obtained following the steps described above -1 each error in this equation. Equation need not be simplified. Deduct one mark if the horizontal and vertical components at A have been interchanged As main scheme	

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