Mark Scheme(Results)

October 2016

Pearson Edexcel International A Level in Mechanics 2 (WME02/01)

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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.

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
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.

'A' marks
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.

'B' marks
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 √ 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
- ⌐ 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

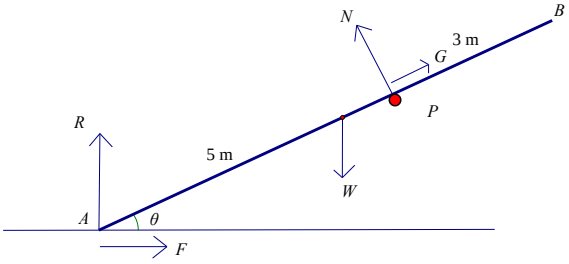
  PCLM Principle of conservation of linear momentum

  RHS, LHS Right hand side, left hand side.

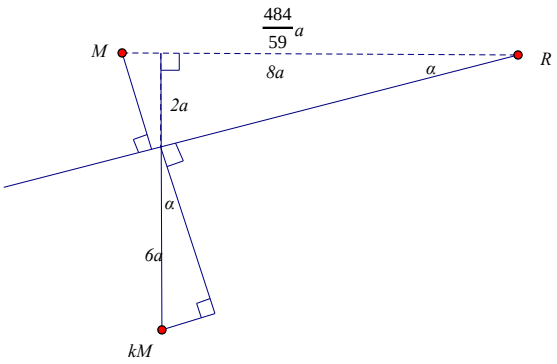
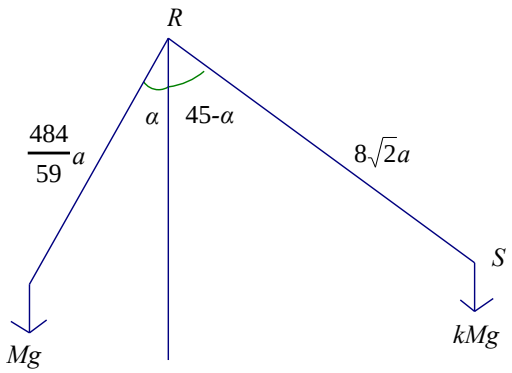
Q	Scheme	Marks	Notes
1a	Take moments about the x-axis:	M1	All terms needed and no extras. Must be dimensionally correct. Condone sign errors
	$m\times 2+4m\times 3-km\times 4=0$	A1	Correct unsimplified equation
	$4k=14,\ \ k=3.5$	A1	Or equivalent
		(3)	
1b	Take moments about the y-axis: $m\times -3+4m\times 4+km\times 6=(5+k)m\times c$	M1	Allow when seen. All terms needed. Must be dimensionally correct. Condone sign errors.
	$-3+16+21(6k)=8.5c$	A1ft	ft their k
	$c=4$	A1	
		(3)	
		[6]	
2	Form impulse-momentum equation:	M1	Must be dimensionally correct
	$2\mathbf{v}-2\times 3\mathbf{i}=\lambda(\mathbf{i}-2\mathbf{j})$	A1	Correct unsimplified
	$2\mathbf{v}=(6+\lambda)\mathbf{i}-2\lambda\mathbf{j}\ \ \left(\mathbf{v}=\frac{1}{2}(6+\lambda)\mathbf{i}-\lambda\mathbf{j}\right)$	A1	$\mathbf{v}$ or $2\mathbf{v}$
	Magnitude of $\mathbf{v}$ (or $2\mathbf{v}$):	M1	Correct application of Pythagoras to form an equation in λ
	$(6+\lambda)^2+4\lambda^2=144$ or equivalent	A1	Correct unsimplified equation in λ
	$5\lambda^2+12\lambda-108=0$	A1	Correct 3 term quadratic in λ
	$(5\lambda-18)(\lambda+6)=0$ solve for λ	M1	Solve a 3 term quadratic in λ
	$\lambda=-6,\ \ \lambda=3.6$	A1	Or equivalent
		(8)	
SC	If a candidate gets far enough to spot that $\lambda=-6$ is a solution, but they do not have a method to find the second solution allow B1 (the final M1 on epen) This gives them a max score of 4/8.		
		[8]	
3a	Form work-energy equation	M1	Need both terms on RHS. Must be dimensionally correct. Condone sign errors

Q	Scheme	Marks	Notes
	Change in energy $= \pm\left(\frac{1}{2}\times 4\times 6^2 - 4g\times 10\sin\alpha\right)$	A2	-1 each error
	$= 72 - 40g\times\frac{1}{7} = 16\,(\text{J})$ ***given answer***	A1	-16 is A0. Condone -16 becoming +16
		(4)	
3a alt	Complete strategy using *suvat* and N2L to find the work done	M1	
	$v^2 = u^2 + 2as \Rightarrow 36 = -20a \quad (a = -1.8)$	A1	
	$Fr + 4g\sin\theta = 4\times(\text{their } 1.8)$ $(Fr = 1.6)$	A1	
	Work Done = $1.6\times 10 = 16\,(\text{J})$ ***given answer***	A1	
		(4)	
	NB: For 3(b) must be using work-energy		
3b	Considering the whole journey: $\frac{1}{2}\times 4v^2 = \frac{1}{2}\times 4\times 36 - 2\times 16$	M1	Requires all 3 terms. Must be dimensionally correct. Condone sign errors
		A1	Correct unsimplified equation
	$v^2 = 20, \quad v = 4.47\,(\text{m s}^{-1})$ (4.5)	A1	Accept $2\sqrt{5}$
		(3)	
3b alt	Working from B to A: $\frac{1}{2}\times 4\times v^2 + 16 = 40g\sin\alpha$	M1	Requires all 3 terms. Must be dimensionally correct. Condone sign errors
		A1	Correct unsimplified equation
	$v^2 = 20, \quad v = 4.47\,(\text{m s}^{-1})$ (4.5)	A1	Accept $2\sqrt{5}$
		(3)	
		[7]	
4a	Differentiate **p** to obtain **v**:	M1	
	$\mathbf{v} = \left(3t^2 - 9t - 24\right)\mathbf{i} + \left(-3t^2 + 6t + 12\right)\mathbf{j}$	A1	
	Equate coefficients and obtain quadratic in	DM1	Dependent on preceding M1

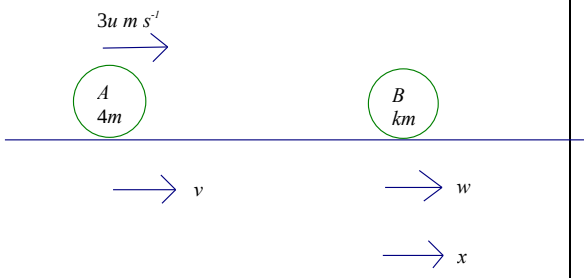
Q	Scheme	Marks	Notes
	T: $3T^2-9T-24=-3T^2+6T+12$ $6T^2-15T-36=0$		
	Solve for T: $3(2T+3)(T-4)=0$,	M1	Independent. Solve a 3 term quadratic in T
	$T=4$	A1	
		(5)	
4b	Differentiate **v** to obtain **a**:	M1	
	$\mathbf{a}=(6t-9)\mathbf{i}+(-6t+6)\mathbf{j}$	A1	
	Use their T: $\mathbf{a}=(6T-9)\mathbf{i}+(-6T+6)\mathbf{j}=15\mathbf{i}-18\mathbf{j}$	DM1	Dependent on the preceding M1
	Use Pythagoras: $\lvert\mathbf{a}\rvert=\sqrt{15^2+18^2}$	M1	
	$=\sqrt{549}=23.4\,(\text{m s}^{-2})$	A1	23.4 or better
		(5)	
		[10]	

Q	Scheme	Marks	Notes
5a			
	Take moments about A:	M1	Must be dimensionally correct. Condone sin/cos confusion
	$5N = 4\cos\theta W$	A1	
	$N = \frac{12}{25}W = 0.48W$ ***Given Answer***	A1	
		(3)	
5b	$G = \frac{1}{4}N = 0.12W$	B1	Seen or implied
	Resolve vertically	M1	Needs all terms. Condone sin/cos confusion and sign errors
	$\updownarrow: R + N\cos\theta + G\sin\theta = W$	A1	$\left(R = 0.616W\right)$
	Resolve horizontally	M1	Needs all terms. Condone sin/cos confusion and sign errors
	$\leftrightarrow: F + G\cos\theta = N\sin\theta$	A1	$\left(F = 0.312W\right)$
	$\mu = \frac{N\sin\theta - G\cos\theta}{W - N\cos\theta - G\sin\theta}$	DM1	Use $F = \mu R$ to find μ Dependent on 2 preceding M marks
	$= \frac{0.48W \times 0.8 - 0.12W \times 0.6}{W - 0.48W \times 0.6 - 0.12W \times 0.8} = \frac{0.312}{0.616}$		
	$= 0.51 \quad (0.50649\ldots) \quad \left(\frac{39}{77}\right)$	A1	
		(7)	
		[10]	
	NB, One of the two equations required for part (b) could be a moments equation: M(P) $1\times W\cos\theta + 5F\sin\theta = 5R\cos\theta$ M(B) $3N + 8R\cos\theta = 4W\cos\theta + 8F\sin\theta$		

<table>
<tr><th>Q</th><th>Scheme</th><th>Marks</th><th>Notes</th></tr>
<tr><td>6a</td><td>
<table>
<tr><td></td><td>Disc</td><td>C_1</td><td>C_2</td><td>L</td></tr>
<tr><td>Mass ratio</td><td>64</td><td>1</td><td>4</td><td>59</td></tr>
<tr><td>Dist from R</td><td>$8a$</td><td>$12a$</td><td>$4a$</td><td>d</td></tr>
</table>
</td><td>B1
B1</td><td>Mass ratio
Distances</td></tr>
<tr><td></td><td>Moments about tangent through C:</td><td>M1</td><td>Or a parallel axis. Needs all terms.
Must be dimensionally correct.
Condone sign errors</td></tr>
<tr><td></td><td>$64\times 8a - 1\times 12a - 4\times 4a = 59d$</td><td>A1</td><td>Correct unsimplified equation.
Accept a vector equation.
$\frac{460}{59}a$ from P, $\frac{12}{59}a$ from O</td></tr>
<tr><td></td><td>$d = \frac{484}{59}a$ *Given answer*</td><td>A1</td><td>Need to see supporting working. e.g. a scalar equation in d</td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td>6b</td><td>For centre of mass of L + particle:</td><td></td><td></td></tr>
<tr><td></td><td>distance of combined c of m from R:</td><td>M1</td><td></td></tr>
<tr><td></td><td>Horizontal $\bar{x} = \frac{\frac{484}{59}aM + 8akM}{(1+k)M}$</td><td>A1</td><td></td></tr>
<tr><td></td><td>Vertical $\bar{y} = \frac{8akM}{(1+k)M}$</td><td>A1</td><td></td></tr>
<tr><td></td><td>Use of $\tan\alpha = \frac{1}{4} = \frac{8k}{\frac{484}{59}+8k}$</td><td>M1</td><td>Condone use of tan the wrong way up.</td></tr>
<tr><td></td><td>$32k = \frac{484}{59} + 8k$, $k = \frac{121}{354}$</td><td>A1</td><td>0.342</td></tr>
<tr><td></td><td></td><td>(5)</td><td></td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td>6balt</td><td>C if m lies at the intersection of (the line through pt from (a) and S) and (the line through R with gradient 1/4)</td><td>M1</td><td></td></tr>
<tr><td></td><td>i.e. $y = -\frac{118}{3}x - 8a$ and $y = \frac{1}{4}x - 2a$</td><td>A1</td><td></td></tr>
<tr><td></td><td>$\Rightarrow x = -\frac{72}{475}a$</td><td>A1</td><td></td></tr>
<tr><td></td><td>Moments about O: $-\frac{12}{50}a = -(k+1)\frac{72}{475}a$</td><td>M1</td><td></td></tr>
<tr><td></td><td>$k = \frac{121}{354}$</td><td>A1</td><td></td></tr>
<tr><td></td><td></td><td>(5)</td><td>See over page for more alternative methods.</td></tr>
</table>

Q	Scheme	Marks	Notes
6b alt			
	Take moments about axis through R : $M \times \frac{484}{59} a \sin\alpha = kM \times 6a \cos\alpha$	M1A2	Condone sin/cos confusion
	Solve for k : $6k = \frac{484}{59}\tan\alpha = \frac{121}{59}$, $k = \frac{121}{354}\left(= 0.342\right)$	M1A1	
		(5)	
6balt			
	Moments: $Mg \times \frac{484}{59} a \sin\alpha = kMg \times 8a\sqrt{2}\sin\left(45-\alpha\right)$	M1A2	
	$\frac{484}{59}\sin\left(14.036..\right) = k \times 8\sin\left(30.96...\right)$	M1	
	$k = 0.342$	A1	
		(5)	
		[10]	

Q	Scheme	Marks	Notes
7	Vertical component of velocity:	M1	
	$-4 = \lambda - gT$	A1	Accept with their λ
	Kinetic energy: $\frac{1}{2}\times\left(\frac{1}{2}m\left(3^2+\lambda^2\right)\right)=\frac{1}{2}m\left(3^2+4^2\right)$	M1	
		A2	-1 each error. $\frac{1}{2}$ on wrong side is one error
	Solve for λ and T: $9+\lambda^2=50,\ \ \lambda=\sqrt{41}\left(=6.40....\right)$	DM1	Dependent on both preceding M marks
	$T=\frac{4+\lambda}{g}=\frac{4+\sqrt{41}}{g}\left(=1.06\right)$	A1	
	i component of position vector $=3T=3\frac{4+\sqrt{41}}{g}=3.2$ (**i**) (their T)	B1ft	> 2 s.f. is B0
	j component of position vector $=\lambda T-\frac{1}{2}gT^2$ for their λ, T	M1	
	= 1.3(**j**)	A1	(1.1 from T=1.1 is premature approximation $\rightarrow$ A0)
		(10)	
	Alternative for **j** component: $v^2=u^2+2as\Rightarrow\left(-4\right)^2=\lambda^2-2gs$ M1		
	$\Rightarrow s=\frac{25}{2g}=1.3$ A1		
		[10]	
			NB the Q asks for 2 s.f. Only penalise > 2 s.f. once

Q	Scheme	Marks	Notes
8a			
	CLM: $12mu = 4mv + kmw$	M1	All 3 terms and dimensionally consistent.
	$(12u = 4v + kw)$	A1	Correct unsimplified equation
	Impact law: $w - v = \frac{2}{3} \times 3u = 2u$	M1	Must be used the right way round.
	$(w = v + 2u)$	A1	Correct unsimplified equation
	Solve for v: $12u = 4v + k(v + 2u)$	DM1	Dependent on both preceding M marks
	$(4 + k)v = 12u - 2ku$		
	$\lvert v \rvert = \left\lvert \frac{2u(6-k)}{k+4} \right\rvert$ (m s^{-1})	A1	Or equivalent. **Must be positive**
		(6)	
8b	Same direction $\Rightarrow v > 0$	M1	
	$\Rightarrow (0 <) k < 6$	A1	If stated, minimum value must be 0
		(2)	
8c	$k = 4 \Rightarrow v = \frac{u}{2}, \quad w = \frac{5u}{2}$	B1	
	CLM & Impact: $4m \times \frac{5u}{2} = 4mx + 2my$ $(10u = 4x + 2y)$	M1	Both equations
	$y - x = \frac{2}{3} \times \frac{5u}{2} \left(= \frac{5u}{3} \right)$	A1ft	In any form, follow their w Both equations correct
	Solve for x: $10u = 4x + 2\left(x + \frac{5u}{3} \right)$	M1	
	$6x = \frac{20u}{3}, \quad x = \frac{10u}{9}$	A1	
	$\frac{u}{2} < \frac{10u}{9} \Rightarrow A$ will not collide with B again ***given answer***	A1	CSO
		(6)	
		[14]	