Mark Scheme (Results)

January 2015

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.
- 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:

<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
- ⎣ 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. 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.

6. 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.
- 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.

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January 2015
WME02/01 Mechanics 2
Mark Scheme

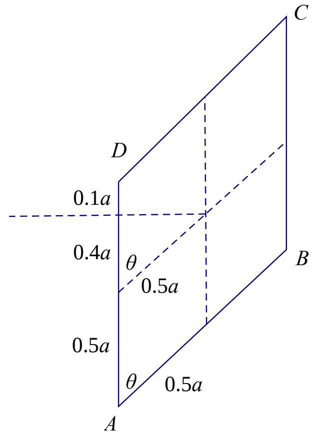
Question Number	Scheme	Marks	
1(a)	Use of $\mathbf{I} = m\mathbf{v} - m\mathbf{u}$	M1	Used
	$= 0.6(2\mathbf{i} + 3\mathbf{j} - 4\mathbf{i} + 2\mathbf{j})$ $= 0.6(-2\mathbf{i} + 5\mathbf{j})$ $(-1.2\mathbf{i} + 3\mathbf{j})$	A1	correct unsimplified Allow for subtraction the wrong way round. or simplified equivalent
	$\lvert\mathbf{I}\rvert = 0.6\sqrt{4+25}$	M1	use of Pythagoras on their impulse
	= 3.23	A1	Or better $\frac{3}{5}\sqrt{29}$, 3.231098..... condone $0.6\sqrt{29}$
		[4]	
1(b)	KE lost = $\frac{1}{2}\times 0.6\times\left(\lvert 4\mathbf{i} - 2\mathbf{j}\rvert^2 - \lvert 2\mathbf{i} + 3\mathbf{j}\rvert^2\right)$	M1	Change in KE. Terms of correct structure. Subtract in either order.
	$= \frac{1}{2}\times 0.6\times(20-13)$	A1	Correct unsimplified. Accept ± Allow after approximation e.g. $\frac{1}{2}\times 0.6\times\left(4.5^2 - 3.6^2\right)$
	=2.1 (J)	A1	CAO
		[3]	

Question Number	Scheme	Marks	
2(a)	Driving force = $150 + 500g\sin\theta$	M1	Requires both terms. Condone sign and sin/cos confusion
	$= 150 + 500\times 9.8\times\frac{1}{20}(=395)$ (N)	A2	-1 each error Use of 9.81 is an error
	Rate of work = $20\times(395)$	M1	Use of $P = Fv$
	= 7.9 kW	A1	or 7900 (W)
		[5]	
	If they use $\theta = 2.87$ this leads to inaccurate answers. Allow all the marks apart from the final A1 in each part, but watch out for those who tell you $\theta = 2.87$ and actually use the correct value and score full marks.		
2(b)	$150d + 500g\times\sin\theta\times d\left(=(\text{their } 395)d\right) = \frac{1}{2}\times 500\times 20^2$	M1	**The question specifies work-energy** Energy equation. Requires all 3 terms (of correct form), with no duplication, but condone sign errors and sin/cos confusion.
	$150d + 500g\times\frac{1}{20}\times d\left(=(\text{their } 395)d\right) = \frac{1}{2}\times 500\times 20^2$	A2	Correct unsimplified equation in *d*. -1 each error
			M1A2 available for correct work leading to -ve *d*
	$d = 250$ (m)	A1	accept 253 (answer must be +ve)
		[4]	

Question Number	Scheme	Marks	
3(a)	$\mathbf{v}=\left(\frac{1}{2}t^3-4\lambda t\right)\mathbf{i}+\left(10t-\lambda\right)\mathbf{j}$	M1	Differentiate **r.** Attempt seen for one or both components. (See at least one power going down)
		A1	**i** component correct
		A1	**j** component correct Allow if M1 earned here but **j** component not seen in (a) but then seen correct in (b)
	$\frac{1}{2}t^3-4\lambda t=0$ when $t=4$, $\frac{64}{2}-16\lambda=0$	DM1	Dependent on the first M1. Set **i** component of their **v** equal to zero Allow with no **j** component or incorrect **j** component
	$\lambda=2$	A1	***Given answer*** Allow with no **j** component or incorrect **j** component
		[5]	
3(b)	$t=4, \lambda=2$ speed = 38 (m s^{-1})	B1	Must be a scalar, not a vector.
		[1]	
3(c)	$\mathbf{a}=\left(\frac{3t^2}{2}-4\times 2\right)\mathbf{i}+10\mathbf{j}$	M1	Differentiate **v**
	= 16**i** + 10**j** ISW	A1	CSO
		[2]	
3(d)	$t=0$, $\mathbf{r}=5\mathbf{i}$	B1	
	$t=4$, $\mathbf{r}=-27\mathbf{i}+72\mathbf{j}$	B1	
	Distance = $\sqrt{32^2+72^2}$ (m)	M1	Use Pythagoras to find $\lvert\mathbf{r}_4-\mathbf{r}_0\rvert$ for $\mathbf{r}_0\neq 0$, $\mathbf{r}_4\neq 0$
	$=8\sqrt{97}=78.8$ (m)	A1	78.7908..., $8\sqrt{97}$
		[4]	

Question Number	Scheme	Marks	
4(a)	Use total height A to C	B1	$a+a\cos\theta$ seen
	the centres of mass of the rhombuses lie on a straight line passing through the centre of mass. $0.9a=\frac{1}{2}(a+a\cos\theta)$	M1 A2	using the symmetry of the figure. Condone sin/cos confusion. -1 each error
	$\cos\theta=0.8$	A1	***Given answer***
alt1	Distance from A to centre of rhombus $=a\cos\frac{\theta}{2}$	B1	
	$\lambda.a\cos\frac{\theta}{2}.\cos\frac{\theta}{2}+\lambda.a\cos\frac{\theta}{2}\cos\frac{\theta}{2}=2\lambda\times0.9a$	M1 A2	Taking moments about an axis through A parallel to FB. Condone sin/cos confusion. -1 each error
	$\cos^2\frac{\theta}{2}=0.9$		
	$\cos\theta=2\cos^2\frac{\theta}{2}-1=0.8$	A1	***Given answer*** From exact working
alt2	Distance from A to centre of rhombus $=a\cos\frac{\theta}{2}$	B1	
	the centres of mass of the rhombuses lie on a straight line passing through the centre of mass. $a\cos\frac{\theta}{2}\times\cos\frac{\theta}{2}=0.9a$	M1 A2	using the symmetry of the figure. Condone sin/cos confusion. -1 each error
	$\cos^2\frac{\theta}{2}=0.9$		
	$\cos\theta=2\cos^2\frac{\theta}{2}-1=0.8$	A1	***Given answer*** From exact working
	Working backwards from $\cos\theta=0.8$ to deduce that the distance is 0.9a is acceptable for 5/5		

Question Number	Scheme	Marks	
alt 3	EFBC: $2a^2\sin\theta$, $a\cos\theta+\frac{a}{2}$; EDC: $a^2\sin\theta\cos\theta$, $a+\frac{2}{3}a\cos\theta$; FAB: $a^2\sin\theta\cos\theta$, $\frac{2}{3}a\cos\theta$; lamina: $2a^2\sin\theta$, $0.9a$	B1	Correct division of lamina with correct mass ratios
	$2a^2\sin\theta\left(a\cos\theta+\frac{a}{2}\right)-a^2\sin\theta\cos\theta\left(\frac{2}{3}a\cos\theta+a-\frac{2}{3}a\cos\theta\right)$ $=2a^2\sin\theta\times0.9a$	M1 A2	Moments equation – addition and subtraction of terms consistent with their division. -1 each error
	$\cos\theta=0.8$	A1	***Given answer***
alt 4	EDF & BCD: $2\times\frac{1}{2}a^2\sin\theta$, $\frac{2}{3}a(1+\cos\theta)$; AFD & ADB: $2\times\frac{1}{2}a^2\sin\theta$, $\frac{1}{3}a(1+\cos\theta)$; lamina: $2a^2\sin\theta$, $0.9a$	B1	Correct division of lamina with correct mass ratios
	$2\times\frac{1}{3}a(1+\cos\theta)\times\frac{1}{2}a^2\sin\theta+2\times\frac{2}{3}a(1+\cos\theta)\times\frac{1}{2}a^2\sin\theta$ $=2a^2\sin\theta\times0.9a$	M1 A2	Moments equation addition and subtraction of terms consistent with their division. -1 each error
	$\cos\theta=0.8$	A1	***Given answer***
Alt5	$AM=a\cos\theta$	B1	Let M be the midpoint of FB. Centre of mass lies at the midpoint of DM
	$DM=a-a\cos\theta$		
	$0.9a=a\cos\theta+\frac{1}{2}(a-a\cos\theta)$	M1 A2	
	$0.4a=\frac{1}{2}a\cos\theta,\quad \cos\theta=0.8$	A1	***Given answer***
		[5]	

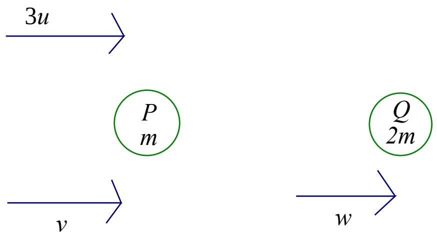
Question Number	Scheme	Marks	
Alt6			Using the symmetry of the figure, the centres of mass of the rhombuses lie on a straight line passing through the centre of mass.
		B1	$0.4a$ seen or implied
	$\cos\theta = \dfrac{0.4a}{0.5a}$	M1 A2	Trig ratio for θ. Condone sin/cos confusion. Correct unsimplified expression
	$= 0.8$	A1	
		[5]	
4(b)		M1	Taking moments about B Must have both terms. Condone trig & sign errors
	$kW\left(a\cos\theta\right) = W\left(0.9a - a\cos\theta\right)$	A2	-1 each error
	$0.8kW = 0.1W, \quad k = \dfrac{1}{8}$	A1	
4(b) alt	Centre of mass is on BF .	M1	Taking moments about A
	$0.9aW = \left(k+1\right)W \times a\cos\theta = \left(k+1\right)\times 0.8aW$	A2	-1 each error
	$k = \dfrac{1}{8}$	A1	
		[4]	

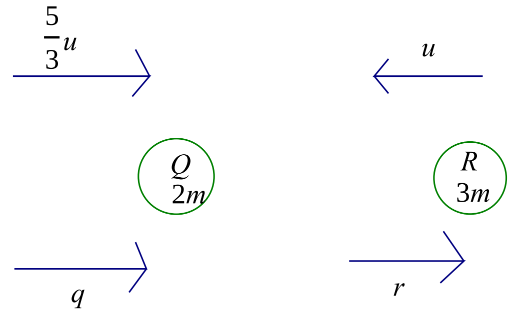
Question Number	Scheme	Marks	
5(a)	Moments about A: $F\times\frac{5a}{4}=mga\cos\theta+2kmga\cos\theta$	M1	Requires all 3 terms. Condone trig & sign errors
		A2	-1 each error
	$F=\frac{4mg\cos\theta}{5}(1+2k)=\frac{16}{25}mg(1+2k)$	A1	Substitute for $\cos\theta$ and obtain **GIVEN ANSWER**
		[4]	
5(b)	$H=F\sin\theta=\left(\frac{16}{25}mg(1+2k)\sin\theta\right)$	M1	Resolve horizontally
	$=\frac{48}{125}mg(1+2k)$	A1	
	$V=mg(1+k)-F\cos\theta$	M1	Resolve vertically. Need all three terms. Condone trig & sign errors
		A1	Correct unsimplified
	$=mg(1+k)-\frac{64}{125}mg(1+2k)\left(=\frac{mg}{125}(61-3k)\right)$	A1	Correct unsimplified with X and $\cos\theta$ substituted. Accept $\pm$
5(b) alt	$\frac{4}{5}H+\frac{3}{5}V=\frac{3}{5}mg+\frac{3}{5}kmg\quad(4H+3V=3mg(1+k))$	M1	Resolve parallel to the rod or perpendicular to the rod
	$\frac{4}{5}V+F=\frac{3}{5}H+\frac{4}{5}mg+\frac{4}{5}kmg$ $\left(V=\frac{3}{4}H+mg(1+k)-\frac{4}{5}mg(1+2k)\right)$	M1	Obtain second equation in H and V and solve for H or V
		A1	Both equations correct unsimplified
	$H=\frac{48}{125}mg(1+2k)$	A1	Or equivalent
	$V=mg(1+k)-\frac{64}{125}mg(1+2k)\left(=\frac{mg}{125}(61-3k)\right)$	A1	Or equivalent. Accept $\pm$
		[5]	

Question Number	Scheme	Marks	
5(b) alt2	$R+F=mg(1+k)\times\frac{4}{5}$ $\left(R=\frac{mg}{25}(4-12k)\right)$	M1	Component R perpendicular to the rod at A and L parallel to the rod. Attempt to find both.
	$L=mg(1+k)\times\frac{3}{5}$		
	$H=\frac{4}{5}L-\frac{3}{5}R$, $V=\frac{4}{5}R+\frac{3}{5}L$	M1 A1	Express V and H in terms of R and L
	$H=\frac{12mg}{25}(1+k)-\frac{3mg}{125}(4-12k)\left(=\frac{48mg}{125}(1+2k)\right)$	A1	Correct unsimplified
	$V=\frac{4}{5}\times\frac{mg}{25}(4-12k)+\frac{3}{5}\times\frac{3mg}{5}(1+k)\left(=\frac{mg}{125}(61-3k)\right)$	A1	Correct unsimplified. Accept $\pm$
		[5]	
5(c)	Use of $H=V$ to form equation in k	M1	
	$\frac{48}{125}mg(1+2k)=mg(1+k)-\frac{64}{125}mg(1+2k)$	DM1	Correct for their H, V and solve for k.
	$k=\frac{13}{99}$	A1	0.13 or better $(0.\dot{1}\dot{3})$
		[3]	

Question Number	Scheme	Marks	
6(a)	Conservation of energy: $\frac{1}{2}m\times 49+10mg=\frac{1}{2}mv^2$	M1	Equation must include all three terms.
		A2	-1 each error
	$v=15.7$ m s^{-1}	A1	Accept 16 Not 15.6
(a)alt	Find horizontal and vertical components of speed at *B*	M1	Use of *suvat* for both components and combine
	$v_x=7\cos 55$	A1	
	$(v_y)^2=(7\sin 55)^2+20g$	A1	
	$v=15.7$ m s^{-1}	A1	Accept 16 Not 15.6
		[4]	
	NB: Use of 7 in $v^2=u^2+2as$ scores 0/4 in (a) but allow ft marks in subsequent parts if that work follows correctly		
6(b)	$\cos\theta=\frac{7\cos 55}{\text{their } v}$, $\tan\theta=\frac{\text{their } v_y}{7\cos 55}$	M1	Correct trig to form equation in a relevant angle
	$\cos\theta=\frac{7\cos 55}{\sqrt{49+20g}}$, $\tan\theta=\frac{\sqrt{(7\sin 55)^2+20g}}{7\cos 55}$	A1	
	$\theta=75.1°$ to the horizontal (75) (75.2 from 15.7)	A1	14.9° to the vertical (direction seen or implied) A0 if magnitude and direction contradict.
		[3]	
6(c)	Vertical distance: $-10=(7\sin 55)t-4.9t^2$	M1	Use of *suvat* - condone sign errors
		A2	-1 each error
	$t=\frac{7\sin 55+\sqrt{(7\sin 55)^2+40\times 4.9}}{9.8}$	DM1	Solve for *t*. Incorrect answers must be supported by working.
	=2.13 (s)	A1	Accept 2.1

Question Number	Scheme	Marks	
(c)alt		M1	Complete strategy to find t.
	Vertical component of speed at B $= \text{their } 15.7 \times \sin(\text{their } 75.1)$	A1	
	$v = u + at$: $15.1... = (-7\sin 55) + gt$	DM1	Use *suvat.* Condone sign error(s)
		A1	
	t =2.13 (s) (2.1)	A1[5]	Accept 2.1
6(c) alt 2		M1	Complete strategy for time to top + Top to ground
	Time to top: $0 = 7\sin 55 - gt$, $t_1 = 0.5851....$	A1	
	Distance to top: $0 = (7\sin 55)^2 - 2\times 9.8s$, $s = 1.6775..$	DM1	
	Time to fall 11.68: $11.68 = \frac{1}{2}gt^2$, $t_2 = 1.5437...$	A1	
	Total time $= t_1 + t_2 = 2.13$ (s)	A1	
6(c) alt 3		M1	Complete strategy for time to level + time to fall 10 m
	$-7\sin 55 = 7\sin 55 - gt$, $t_1 = 1.17...$	A1	
	Time to fall 10 m: $-10 = -7\sin 55t - 9.8t^2$	DM1	
	$t_2 = 0.959...$	A1	
	Total time $= t_1 + t_2 = 2.13$ (s)	A1	
		[5]	

Question Number	Scheme	Marks	
7(a)(i)			
	CLM: $3mu = mv + 2mw \quad (3u = v + 2w)$	M1	Requires all three terms, but condone sign errors
		A1	
	Impact: $w - v = 3eu$	M1	Impact law applied the right way round, but condone sign errors
		A1	A0 here if the signs in the two equations are not consistent.
	$\Rightarrow 3w = 3u(1+e), \quad w = u(1+e)$	DM1	Dependent on the 2 previous M marks. Solve for w or v.
(ii)	$\Rightarrow v = w - 3eu = u - 2ue$ speed = $\lvert u(1-2e) \rvert$	A1	Both speeds correct. Must both be positive.
		[6]	
7(b)	Change in direction $1 - 2e < 0$	M1	Correct inequality for reversal of direction (for their v)
	$(1 \geq) e > \frac{1}{2}$	A1	CWO. $e \leq 1$ not required.
		[2]	

Question Number	Scheme	Marks	
7(c)	$v = -\frac{u}{3}$ and $w = \frac{5}{3}u$	B1	
			
	$2m \times w - 3mu = 2mq + 3mr$ $r - q = e(w+u)\left(= \frac{16u}{9}\right)$	M1	CLM & impact equations
		A1	Both correct
	$\frac{u}{3} = 2q + 3r$, $3r - 3q = \frac{16u}{3}$	DM1	Dependent on previous M1. Solve for q
	$5q = -5u$, $q = -u$	A1	
	$u > \frac{u}{3}$ therefore Q will collide with P a second time	A1	**Given answer**
		[6]	

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