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Mark Scheme (Results)

January 2016

Pearson Edexcel International A Level in Mechanics 2 (WME02)

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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 GCE 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 $\surd$ 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)

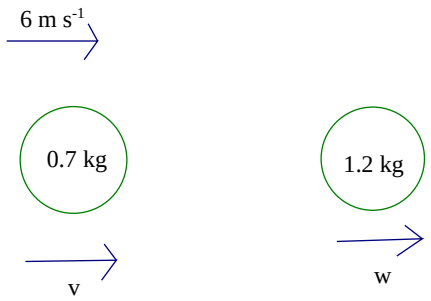
  HL Hooke's Law

  SHM Simple harmonic motion

  PCLM Principle of conservation of linear momentum

  RHS, LHS Right hand side, left hand side.

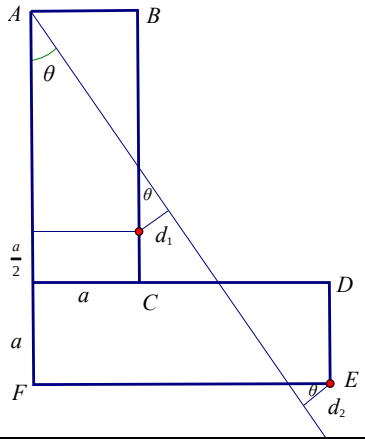
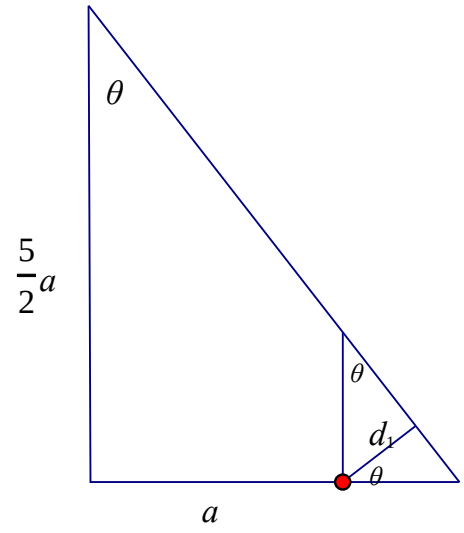
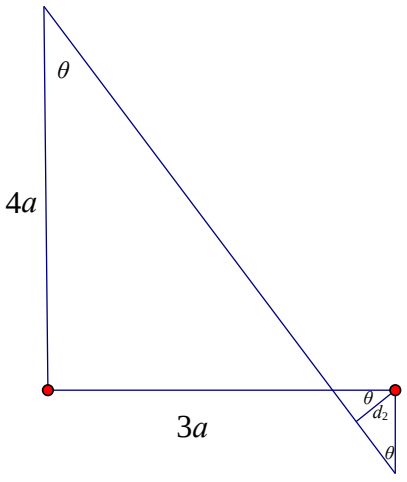
Question Number	Scheme	Marks	Notes
1a	Resolving parallel to the plane	M1	Condone trig confusion
	$D = 900g\sin\theta + 800$	A1	
	$\frac{900}{25}g + 800\left(=1152.8\right)$ (N)		
	Work done : Their $D \times$ distance $= 1152.8 \times 14 \times 10$	M1	Independent. For use of 14 x 10 x their D
	$= 161392 = 161\,\text{kJ}$ (160)	A1	Accept 161000 (J), 160000 (J) Ignore incorrect units.
		(4)	
	Alternative using energy:		
	Work done $= 900gd\sin\theta + 800d$ M1A1		Allow with incorrect d
	Use of $d = 14 \times 10$ M1		Independent – allow in an incorrect expression
	$= 161392 = 161\,\text{kJ}$ (160) A1		
1b	Equation of motion	M1	All terms required. Condone trig confusion and sign errors. Allow with $900a$
	$D - 900g\sin\theta - 800 = 900 \times 0.7$	A1	Correct unsimplified with $a = 0.7$ used Accept with their 1152.8 arising from a 2 term expression in (a).
	$(D - 1152.8 = 900 \times 0.7)$		
	$D = 1782.8$ (N)		
	Use of $P = Fv$ $\quad P = 14 \times \frac{\text{their } D}{1000}$	M1	Independent Treat missing 1000 as misread, so allow for $14 \times$ their$D$ Allow for $\frac{1000P}{14}$ (or $\frac{P}{14}$) in their equation of motion
	$P = 25.0$ (25)	A1	CAO
		(4)	
		[8]	

Question Number	Scheme	Marks	Notes
2.a			
	CLM: $0.7\times 6 = 0.7\times v + 1.2w$	M1	Requires all terms & dimensionally correct
	$(42 = 7v + 12w)$	A1	Correct unsimplified
	Impact:	M1	Used the right way round Condone sign errors
	$w - v = 6e$	A1	
	Equation in e and v only: $42 - 72e = 19v$	DM1	Dependent on the two previous M marks
	Use direction to form an inequality:	M1	Independent. Applied correctly for their v.
	$42 - 72e > 0 \quad \Rightarrow \quad e < \frac{7}{12}$	A1	***Given answer***
		(7)	
2b	Impulse on Q: $I = w\times 1.2$	M1	
	Solve for w : $w = v + 6e = \frac{42 - 72\times\frac{1}{4}}{19} + 6\times\frac{1}{4}$	B1	Accept unsimplified with e substituted. Have to be using w in part (b) $w = \frac{105}{38} = 2.763.....$ seen or implied
	$I = 1.2\times\frac{42}{19}\times\frac{5}{4} = \frac{63}{19}(= 3.32)$ (N s)	A1	3.3 or better
		(3)	
		[10]	
2b alt	Impulse on Q = − impulse on P		
	$= -0.7(v - 6)$ M1		Accept negative here
	$= -0.7\left(\frac{42 - \frac{1}{4}\times 72}{19} - 6\right)$ B1		Substitute for e in their v $v = \frac{24}{19} = 1.263....$ seen or implied Accept negative here.
	$= \frac{63}{19}$ A1		Final answer must be positive. 3.3 or better

Question Number	Scheme	Marks	
3a	Use $\mathbf{v}=\lambda(\mathbf{i}+\mathbf{j})$: $6T^2+6T=3T^2+24$	M1	Form an equation in t, T or λ $\lambda^2-108\lambda+2592=0$
	Solve for T $3T^2+6T-24=0$,	M1	Simplify to quadratic in t, T or λ and solve.
	$(T+4)(T-2)=0$, $T=2$	A1	$T=2$ only
		(3)	
	If they score M1 and then state $T=2$ allow 3/3		
	If they guess $T=2$ and show that it works then allow 3/3.		
	If all we see is $T=2$ with no equation then 0/3 for (a) but full marks are available for (b) and (c).		
3b	Differentiate: $\mathbf{a}=(12t+6)\mathbf{i}+6\mathbf{j}$	M1	Majority of powers going down Need to be considering both components
		A1	Correct in t or T
	$=30\mathbf{i}+12\mathbf{j}$ (m s^{-2})	A1	CAO
		(3)	
3c	Integrate : $\mathbf{r}=\left(2t^3+3t^2(+A)\right)\mathbf{i}+\left(t^3+24t(+B)\right)\mathbf{j}$	M1	Clear evidence of integration. Need to be considering both components Do not need to see the constant(s)
		A2	-1 each error
	If the integration is seen in part (a) it scores no marks at that stage, but if the result is used in part (c) then the M1A2 is available in part (c)		
	$\boldsymbol{OA}=28\mathbf{i}+56\mathbf{j}$ Use their T		
	Distance $=28\sqrt{5}=62.6$ (m)	DM1	Dependent on previous M1 Use of Pythagoras on their $\boldsymbol{OA}$
		A1	63 or better , $\sqrt{3920}$
		(5)	
	NB: Incorrect T can score 2/3 in (b) and 4/5 in (c)		
		[11]	
	.		

Question Number	Scheme	Marks	
4a	Resolve perpendicular to the plane: $R = 2g\cos\alpha$	B1	
	Use $F = \mu R$: $F = \frac{1}{4}\times 2g\times\frac{4}{5}\left(=\frac{2g}{5}\right)$	M1	with $\frac{1}{4}$ and their R (3.92)
	Work done: WD $= 2.5\times F$	DM1	For their F
	$= 2.5\times\frac{2g}{5} = 9.8\,(\text{J})$	A1	Accept g
	If a candidate has found the total work done but you can see the correct terms/processes for finding the work done against friction, give B1M1DM1A0 (3/4)		
		(4)	
4b	Change in PE : $\pm\left(4g\times 2.5 - 2g\times 2.5\sin\alpha\right)$	M1	Requires one gaining and one losing Condone trig confusion
	$= \pm\left(4g\times 2.5 - 2g\times 1.5\right)$	A1	$\pm$ (correct unsimplified)
	PE lost $= 7g = 68.6$ (J)	A1	or 69 (J) Accept $7g$
		(3)	
4c	KE gained + WD = loss in GPE	M1	The question requires the use of work-energy. Alternative methods score 0/4. Requires all terms but condone sign errors (must be considering both particles)
	$\frac{1}{2}\times 4v^2 + \frac{1}{2}\times 2v^2 + \left(\text{their (a)}\right) = \left(\text{their (b)}\right)$	A2	Correct unsimplified. -1 each error
	$3v^2 = 6g$		
	$v = \sqrt{2g} = 4.43\,(\text{m s}^{-1})$	A1	or 4.4. Accept $\sqrt{2g}$
		(4)	
		[11]	
	Alt 4(c)		
	Equations of motion for each particle leading to $T = \frac{12g}{5} = 23.52$ followed by a W-E equation for P: $2.5T = \frac{1}{2}\times 2v^2 + 2g\times 2.5\sin\alpha + \left(a\right)$ M1A2		Equations of motion for each particle leading to $T = \frac{12g}{5} = 23.52$ followed by a W-E equation for Q: $\frac{1}{2}\times 4v^2 + 2.5T = 4g\times 2.5$
	$v = \sqrt{2g} = 4.43\,(\text{m s}^{-1})$ A1		
	Use of $\alpha = 36.9$ gives correct answers to 3 sf		
	Use of $\alpha = 37$ gives correct answers to 2 sf and more than this is not justified, so A0 if they give 3 sf in this case.		

Question Number	Scheme	Marks	Notes
5.	Moments about **vertical** axis (AF):	M1	Requires all terms and dimensionally correct but condone g missing
	$\frac{Mg}{2}\times\frac{1}{2}a+\frac{Mg}{2}\times 1.5a+3akMg=Mg(1+k)\bar{x}$	A2	-1 each error Accept with M and/or g not seen.
	$\left(\bar{x}=\frac{1+3k}{1+k}a\right)$		
	Moments about **horizontal** axis (AB or FE):	M1	Requires all terms and dimensionally correct but condone g missing
	$\frac{Mg}{2}\times 1.5a+\frac{Mg}{2}\times 3.5a+4akMg=Mg(1+k)\bar{y}$	A2	-1 each error. Accept with M and/or g not seen. Do not penalise repeated errors.
	$\left(\bar{y}=\frac{2.5+4k}{1+k}a\right)$		
			Working with axes through F gives $\bar{x}=\frac{1+3k}{1+k}a$ and $\bar{y}=\frac{1.5}{1+k}a$
	SR: A candidate working with a mixture of mass and mass ratio can score 4/6 M1A0A0M1A2		
	Use of $\tan\theta$ with their distances from AF & AB	M1	Must be considering the whole system. Allow for inverted ratio.
	$\tan\theta=\frac{M+3kM}{2.5M+4kM}\left(=\frac{4}{7}\right)$	A1	or exact equivalent
	Equate their $\tan\theta$ to $\frac{4}{7}$ and solve for k: $7M+21kM=10M+16kM$	M1	
	$k=\frac{3}{5}$	A1	CSO
		[10]	
	Alternative for the people who start by considering only the L shape.		
	$\bar{x}=a$ and $\bar{y}=\frac{5}{2}a$ or $\frac{3}{2}a$ M1A2		M1 (for either) requires all terms and dimensionally correct but condone g /M missing. A1 for each correct.
	Combine with the particle M1A2		M1 (for both) requires all terms and dimensionally correct but condone g missing. A1 for each correct.
			See over for a more geometrical approach

Question Number	Scheme	Marks	Notes
			Candidate starts by finding centre of mass at $\left(a, \frac{3}{2}a\right)$ relative to F (or equivalent), M1A2 scored
		M1	Use of $\tan\theta$ with their distances for finding d_1 or d_2.
		A1	Obtain length of a side in a triangle containing d_1 $\left(\frac{5}{2}a\right)\tan\theta - a\left(=\frac{3}{7}a\right)$ Correct for their centre of mass
		A1	$d_1 = \left(\frac{3}{7}a\right)\cos\theta$ Correct for their centre of mass
		M1	Use of $\tan\theta$ to find second distance $3a - 4a\tan\theta = \frac{5}{7}a$
		A1	$d_2 = \frac{5}{7}a\cos\theta$
	Moments about A: $Md_1 = kMd_2$	M1	
	$\frac{3}{7}a\cos\theta = k \times \frac{5}{7}a\cos\theta \Rightarrow k = \frac{3}{5}$	A1	
		(10)	

Question Number	Scheme	Marks	Notes
6a	Taking moments about A:	M1	Requires all terms - condone trig confusion and sign errors
	$bF = 3mga\cos\theta + mg \times 2a\cos\theta$	A2	-1 each error
	$bF = 5mga\cos\theta \qquad F = \dfrac{5mga}{b}\cos\theta$	A1 (4)	***Given answer***
6b	Component of **R** parallel to AB: $\left(R\cos\left(\phi-\theta\right)\right)$	M1	Requires all terms - condone trig confusion
	$= 3mg\sin\theta + mg\sin\theta = 4mg\sin\theta$	A1	Correct unsimplified
	Component of **R** perpendicular to AB:	M1	Requires all terms - condone consistent trig confusion and sign errors
	$\left(R\sin\left(\phi-\theta\right)\right)+F = 4mg\cos\theta$	A1	Correct unsimplified
	Alternatives for M1A1: $M(B)$		$2aR\sin\left(\phi-\theta\right)+3mga\cos\theta = F\left(2a-b\right)$
	$M(C)$		$bR\sin\left(\phi-\theta\right)+\left(2a-b\right)mg\cos\theta = 3mg\left(b-a\right)\cos\theta$
	$\left(R\sin\left(\phi-\theta\right)\right) = 4mg\cos\theta - \dfrac{5mga}{b}\cos\theta$	A1	Correct with F substituted.
	ISW for incorrect work after correct components seen	(5)	
6c	Use of $R\sin\left(\phi-\theta\right) > 0$	M1	
	Solve for b in terms of a: $4 > \dfrac{5a}{b}$, $\left(2a \geq\right) b > \dfrac{5}{4}a$	A1	$2a$ not required CSO
		(2)	
		[11]	
SC	Misread of directions in (b)		NB This MR can score full marks
6(b)	$X = F\sin\theta = \dfrac{5mga}{b}\cos\theta\sin\theta$	M1	Allow with F. Requires all terms - condone trig confusion
		A1	F substituted.
	$Y = 4mg - F\cos\theta = 4mg - \dfrac{5mga}{b}\cos^2\theta$	M1	Allow with F. Requires all terms - condone trig confusion and sign errors.
		A1	Correct unsimplified
		A1	Correct substituted
6(c)	For $\varphi > \theta$, $\tan\phi > \tan\theta$		
	$\tan\varphi = \dfrac{Y}{X} = \dfrac{4-\dfrac{5a}{b}\cos^2\theta}{\dfrac{5a}{b}\cos\theta\sin\theta} > \tan\theta$	M1	
	$4-\dfrac{5a}{b}\cos^2\theta > \dfrac{5a}{b}\sin^2\theta$		
	$4 > \dfrac{5a}{b}\left(\cos^2\theta+\sin^2\theta\right) \quad \Rightarrow b > \dfrac{5}{4}a$	A1	CSO

Question Number	Scheme	Marks	Notes
7a	Equate horizontal components of speeds:	M1	
	$u\cos\theta° = 6\cos 45°\left(=3\sqrt{2}\right)\ \ (4.24....)$	A1	Correct unsimplified
	Use suvat for vertical speeds: $u\sin\theta° - 2g = -6\sin 45°$	M1	Condone sign errors
	$\left(u\sin\theta = 2g - 3\sqrt{2}\right)$	A1	Correct unsimplified
	Divide to find $\tan\theta$: $\tan\theta = \dfrac{2g-6\sin 45}{6\cos 45}$	DM1	Dependent on previous 2 Ms. Follow their components.
	$\left(=\dfrac{2g-3\sqrt{2}}{3\sqrt{2}} = 3.61..\right) \Rightarrow \quad \theta = 74.6\ \ (75)$	A1	$(u = 15.93....)$
		(6)	
7b	At max height, speed $= u\cos\theta (= 3\sqrt{2}$ (m s^{-1}))	B1	
	KE $= \dfrac{1}{2}\times 0.7\times\left(3\sqrt{2}\right)^2$ (J)	M1	Correct for their v at the top, $v \neq 0$
	$= 6.3$ (J)	A1	accept awrt 6.30. CSO
		(3)	
7c	When P is moving upwards at 6 m s^{-1}	M1	Use suvat to find first time $v = 6$
	$u\sin\theta - gt = 3\sqrt{2}$	A1	
	$2g - 3\sqrt{2} - gt = 3\sqrt{2}$	M1	Solve for t
	$t = \dfrac{2g-6\sqrt{2}}{g} = 1.13....$	A1	Sensitive to premature approximation. Allow 1.14.
	$T = 2 - 1.13 = 0.87$	A1	CAO accept awrt 0.87
		(5)	
		[14]	
Alt 7c	$6\sin 45 = 0 + gt$	M1A1	find time from top to A:
	$T = 2t = \dfrac{\dfrac{12\sqrt{2}}{2}}{g} = 0.87$	M1 A1 A1	Correct strategy Correct unsimplified
		(5)	
Alt 7c	: $u\sin\theta = gt$ (their u, θ)	M1	Time to top
	$t = 1.567....$	A1	
	$T = 2\left(2 - 1.567...\right)$	M1A1	
	$= 0.87$	A1	
		(5)	
Alt 7c	Vertical speed at A = - (vertical speed at B) = $= \sqrt{36 - \left(3\sqrt{2}\right)^2} = 3\sqrt{2}$	M1 A1	Or use the 45° angle
	Use $v = u + at$ for $A \rightarrow B$	M1	Correct use for their values
	$-3\sqrt{2} = 3\sqrt{2} - gT$	A1	
	$T = 0.87$	A1	
		(5)	See over for alt 7d

Question Number	Scheme	Marks	Notes
Alt 7d	$v^2 = \left(3\sqrt{2}\right)^2 + \left(u\sin\theta - gt\right)^2 \leq 36$	M1	Form expression for v^2. Inequality not needed at this stage
		A1	Correct inequality for v^2.
	$-\sqrt{18} \leq u\sin\theta - gt \leq \sqrt{18}$	M1	
	$\frac{u\sin\theta - \sqrt{18}}{g} \leq t \leq \frac{u\sin\theta + \sqrt{18}}{g}$	A1	
	$T = \frac{u\sin\theta + \sqrt{18}}{g} - \frac{u\sin\theta - \sqrt{18}}{g} = \frac{2\sqrt{18}}{g} = 0.866$	A1	
		(5)	

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