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Mark Scheme (Results)

Summer 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.
- 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 $\surd$ 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.

June 2016
IAL WME02
Mark Scheme

Question Number	Scheme	Marks
1a	Impulse-momentum equation: $\left(-4\mathbf{i}+3\mathbf{j}\right)=3(\mathbf{v}-\left(3\mathbf{i}+5\mathbf{j}\right))$	M1A1
	$\mathbf{v}=\frac{5}{3}\mathbf{i}+6\mathbf{j}$	A1
	Find the magnitude: speed $=\sqrt{\left(\frac{5}{3}\right)^2+6^2}=6.23$ (m s^{-1}) (6.2 or better)	M1A1 (5)
1b	Gain in KE $=\frac{m}{2}\left(\left\|\mathbf{v}\right\|^2-\left\|\mathbf{u}\right\|^2\right)=\frac{3}{2}\left(\left(\text{their } 6.23\right)^2-\left(3^2+5^2\right)\right)$	**M1A1 ft**
	$=7.17$ (J) (7.2 or better) (must be +ve)	A1 (3)
		[8]
	Notes	
1a	First M1 for $\pm\left(-4\mathbf{i}+3\mathbf{j}\right)=3(\mathbf{v}-\left(3\mathbf{i}+5\mathbf{j}\right))$ (M0 if 3 omitted or wrong mass used or term omitted) First A1 for a correct equation Second A1 for a correct **v** Second M1 for finding the magnitude of their **v** Third A1 for $\frac{\sqrt{349}}{3}$, 6.2 or better.	
1b	M1 for $\pm\frac{3}{2}((\textit{their}6.23)^2-(3^2+5^2))$ (M0 if 3 omitted or wrong mass used or term omitted) Also M0 for $\pm\frac{3}{2}\left\{(\frac{5}{3}\mathbf{i}+6\mathbf{j})^2-(3\mathbf{i}+5\mathbf{j})^2\right\}$ unless it becomes $\pm\frac{3}{2}\left\{((\frac{5}{3})^2+6^2)-(3^2+5^2)\right\}$ First **A1ft** on their **v** for a correct expression Second A1 for 43/6 oe, 7.2 or better.	

Question Number	Scheme	Marks
2a	$F = \frac{10000}{15}$	B1
	Use of "$F = ma$": $F - R = 1800 \times 0.25 (= 450)$ with their F	M1A1**ft**
	$R = \frac{10000}{15}$ - 450 = 220 or better , 650/3 oe (216.6..)	A1 (4)
2b	$F = \frac{12000}{V}$	B1
	Moving at constant speed: $D = mg\sin\theta + 30V$	M1
	$\frac{12000}{V} = 1800g \times \frac{1}{14} + 30V$	A2
	Quadratic in V: $30V^2 + 1260V - 12000 = 0$	
	Solve for V: $V^2 + 42V - 400 = 0 = (V + 50)(V - 8)$	M1
	$V = 8$	A1 (6)
		[10]
	Notes	
2a	B1 for $(F) = \frac{10000}{15}$ seen or implied. B0 for $\frac{10}{15}$ M1 for resolving horizontally First A1 ft for a correct equation with their F Second A1 for 650/3 oe, 220 or better i.e. 217, 216.7, ..	
2b	B1 for (D) = 12000/V seen or implied. B0 for 12/V First M1 for resolving parallel to the plane with a = 0 but neither D nor $\sin\theta$ need to be substituted. First A1 and Second A1 for an equation in V only, A1A0 if one error. Second M1 for solving a 3-term quadratic in V by attempting to factorise or use the formula; this M mark can be implied by a correct answer but an incorrect answer scores M0A0. Third A1 for V = 8	
	N.B. Penalise use of kW ONCE per question	

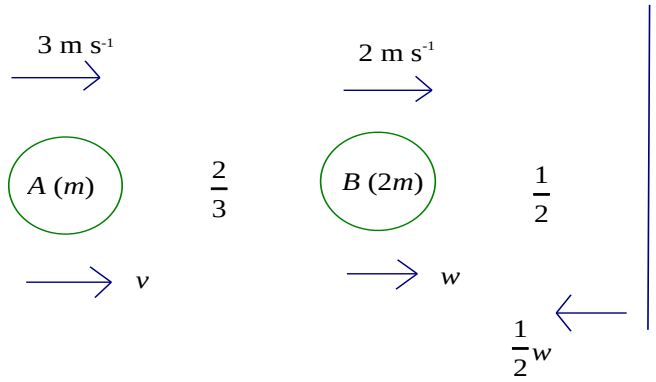
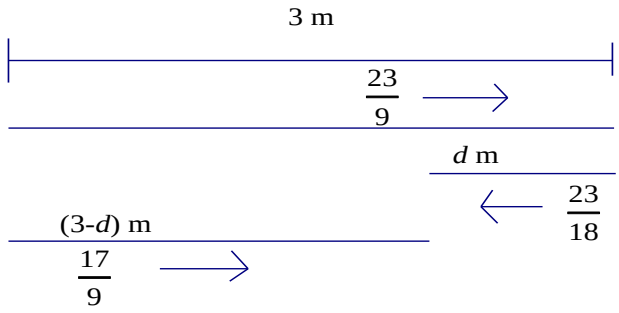
Question Number	Scheme	Marks
3a	Loss in GPE : $3mgd - 2mg \times d\sin\theta = 3mgd - \frac{4}{5}mgd$	M1A1
	$d = \frac{11}{5}mgd$ ***Given answer***	A1 (3)
3b	Must be using **work-energy** $\frac{1}{2}\times 2mv^2 + \frac{1}{2}\times 3mv^2 + \frac{3}{5}mgd = \frac{11}{5}mgd$	M1A2
	$v^2 = \frac{16}{25}gd$	A1 (4)
3c	Use of $s = \frac{u+v}{2}t$ or equivalent: $1.5 = \frac{(0+\sqrt{\frac{24g}{25}})}{2}T$	M1
	$T = 0.98$ or 0.978 or $5\sqrt{30}/28$	A1 (2)
		[9]
	Notes	
3a	M1 for $\pm(3mgd - 2mgd\sin\theta)$ (allow if cos used instead of sin) First A1 for a correct unsimplified expression in $\pm mgd$ Second A1 for given positive answer	
3b	First M1 for a dimensionally correct work-energy equation, with all 4 terms as above, if they use the answer from (a), **OR**: $\frac{1}{2}\times 2mv^2 + \frac{1}{2}\times 3mv^2 + \frac{3}{5}mgd + 2mgd\sin\theta = 3mgd$ i.e. all 5 terms if they don't, but condone sign errors. (M0 if incorrect no. of terms) First A1 and Second A1 for a correct equation, A1A0 if one error. Third A1 for $\frac{16gd}{25}$ oe or $6.3d$ or $6.27d$	
3c	M1 for a complete method to give an equation in T only. (M0 if they just assume a value for a e.g. $a = 0$ or g) A1 for 0.98 or 0.978 or $15/\sqrt{(24g)}$ oe	

Question Number	Scheme	Marks
4a	Mass ratios: $18a^2,\ 9a^2,\ 27a^2$	B1
	Centres of mass: $\frac{3}{2}a,\ 4a,\ \bar{x}$ from AE	B1
	Moments about AE: $18a^2 \times \frac{3}{2}a + 9a^2 \times 4a = 27a^2 \times \bar{x}$	M1A1
	$\bar{x} = \frac{7a}{3}$	A1 (5)
4b	Moments about A: $4g\ \bar{x} = 6aF$	M1 **A1ft**
	Vertical component (Y) of force at $A = 4g$	B1
	Force at A: $\sqrt{X^2 + Y^2}$	M1
	= 42.1 (N) or 42 (N)	A1 (5)
		[10]
	Notes	
4a	First B1 allow any correct ratios i.e. do not need a^2 Second B1 could be scored if distances consistently measured from somewhere else. First M1 for attempt at correct moments equation with correct no. of terms and condone sign errors First A1 for a correct equation Second A1 for $7a/3$, $2.3a$, $2.33a$, or better	
4b	First M1 for a moments equation (could be about A, B, C, D or E), dim correct with correct no. of terms etc and allow sign errors First **A1 ft** for a correct equation with their $\bar{x}$ First B1 for vert component (Y) = $4g$ seen Second M1, independent but must have found an X and a Y, for attempt at magnitude $\sqrt{X^2 + Y^2}$, using their X and Y Second A1 $\frac{2g\sqrt{373}}{9}$ or 42 (N) or 42.1 (N). N.B. Note that $X = F$ <u>Possible moments equations</u>: $M(A): 4g\bar{x} = 6aF$ $M(B): 4g(3a - \bar{x}) + 6aF = 3aY$ $M(C): 4g(6a - \bar{x}) + 3aF + 3aX = 6aY$ $M(D): 4g(3a - \bar{x}) + 6aX = 3aY$ $M(E): 4g\bar{x} = 6aX$	

Question Number	Scheme	Marks
5a	Moments about A: $6g(\times 1)\times \sin 70 = T\sin 30\times 2$	M1A2
	$T = 55.3$(N) or 55 (N)	A1 (4)
5b	Resolve horizontally: $T\cos 50 = R(=35.5)$	B1 **ft**
	Resolve vertically: $T\sin 50 = 6g \pm F$	M1A1 **ft**
	$\lvert F\rvert = 16.5$ $(16.473\ldots)$	
	Use $F = \mu R$: $\mu = \dfrac{6g - T\sin 50}{T\cos 50}$ (with their values)	M1
	= 0.464 or 0.46	A1 (5)
5c	Use of tan and their components: $\tan^{-1}\left(\dfrac{35.5}{16.5}\right)$	M1
	$= 65.1°$ or 65^o to the upward vertical	A1 (2)
	or equivalent (24.9^o or 25^o above the	[11]
	horizontal)	
	Notes	
5a	First M1 for a complete method to find T, with usual rules, correct no. of terms, allow sin/cos confusion, dim correct (missing g is an A error) and allow incorrect angles. First A2 for a correct equation (A1A0 for one error) Third A1 for 55 (N) or 55.3 (N)	
5b	First B1 **ft** for resolving horizontally (T does not need to be substituted) First M1 for resolving vertically with usual rules, must be using 40^0 or 50^0 First A1 **ft** for a correct equation (T does not need to be substituted) Second M1, independent, for use of $F = \mu R$, must have found an F and an R Second A1 for 0.46 or 0.464 **N.B.** They may resolve in other directions e.g. along the rod or perpendicular to the rod or take moments e.g. about B or C First B1 for a correct equation seen M1A1 for the better equation seen, usual rules etc.	
5c	First M1 for a complete method to find the angle (must have found the two components) with either the horizontal or vertical	
	First A1 for 65^0 or 65.1^0 to the upward vertical oe (A0 for just an angle)	
	Or the angle marked on a clear diagram with an arrow.	

Question Number	Scheme	Marks
6a	Horizontal distance: $x = 7t$	B1
	Vertical distance : $y = 7\sqrt{3}\ t - \frac{1}{2}gt^2$	M1A1
	Sub for t : $y = 7\sqrt{3} \times \frac{x}{7} - \frac{g}{2} \times \frac{x^2}{49} = \sqrt{3}x - \frac{g}{98}x^2$ ***Given Answer***	**DM**1A1 (5)
6b	Differentiate to find gradient: $\frac{dy}{dx} = \sqrt{3} - \frac{2gx}{98}$	M1A1
	Sub $x = 20$ & use tan: $\tan^{-1}\left(\sqrt{3} - \frac{40g}{98}\right)$	**DM**1
	$= 66.2°$ or 66^o below the horizontal oe	A1 (4)
	Or :in the direction of (parallel to is A0) (7**i** – 16**j**) or (7**i** – 15.9**j**)	
6balt	$x = 20 = 7t \Rightarrow t = \frac{20}{7}$	M1
	Vertical cpt $= 7\sqrt{3} - \frac{20}{7}g$	A1
	$\theta = \tan^{-1}\left(\frac{7\sqrt{3} - \frac{20g}{7}}{7}\right) = -66.2^0$; 66^o below the horizontal oe	**DM**1A1 (4)
6c	Use the *x/y* ratio to form an equation in T: $7T = 14\sqrt{3}T - gT^2$	M1A1
	Solve for T: $T = \frac{14\sqrt{3} - 7}{g}(= 1.8)$ (1.76)	**DM**1A1 (4)
6c alt	$l = 2l\sqrt{3} - \frac{g}{98}(2l)^2$	M1A1
	$T = \frac{2l}{7} = 1.76$	**DM**1A1 (4)
		[13]
	Notes	
6a	B1 for $x = 7t$ seen or implied M1 for vertical motion equation $y = 7\sqrt{3}t - 1/2\ gt^2$ need correct no. of terms, but condone sign errors First A1 for a correct equation Second **DM**1, dependent on first M1, for substituting for t Second A1 for **given answer**.	

Question Number	Scheme	Marks
6b	First M1 for attempt to differentiate path equation (both powers going down) First A1 for a correct expression Second DM1, dependent on first M1, for putting $x = 20$ and using $\tan^{-1}$ to obtain an angle Second A1 for 66^0 or 66.2^0 below the horizontal or 24^o or 23.8^o to the downward vertical OR the angle marked on a clear diagram with an arrow	
6balt	First M1 for using $x = 20$ in horizontal motion equn to obtain $t = 20/7$ and using $v = u + at$ to obtain vertical speed or any other complete method e.g. put $x = 20$ in equation of path to obtain y , which is then used in $v^2 = u^2 + 2as$ vertically to obtain vertical speed. First A1 for a correct expression for vertical speed Second **DM**1, dependent on first M1, for using ratio of components and $\tan^{-1}$ to obtain an angle OR finding the velocity vector <u>AND</u> referring to its direction ('parallel to' can score M1 but not the A1). Second A1 for 66^0 or 66.2^0 below the horizontal or in the direction of (parallel to is M1A0) $(7\mathbf{i} - 16\mathbf{j})$ or $(7\mathbf{i} - 15.9\mathbf{j})$ or a multiple.	
6c	First M1 for using $\frac{2/}{/} = \frac{7T}{7\sqrt{3}T - 4.9T^2}$ to obtain an equation in *T only* Allow M1 if they have the reciprocal of RHS. First A1 for a correct equation Second **DM**1 for solving the equation for T (**N.B.** if incorrect answer, need to see at least one line of working for this DM mark) Second A1 for $T = 1.76$ or 1.8	
6c alt	First M1 for using the point $(2/, /)$ and the path equation to obtain an equation in $/$ only (or x) First A1 for a correct equation Second DM1 for solving for $/$ or x and using it to obtain a value for T Second A1 for $T = 1.76$ or 1.8 N.B. Allow interchange of $/$ and $2/$ for the method marks.	

Question Number	Scheme	Marks
7a		
	CLM : $3m+4m=mv+2mw \quad (7=v+2w)$	M1A1
	Impact: $w-v=\frac{2}{3}(3-2)$	M1A1
	Solve for w: $w=\frac{23}{9}$ ***Given answer***	M1 A1
	$v=\frac{17}{9}$	A1 (7)
7b		
	Speed of B after hitting wall = $\frac{23}{18}$ (m s^{-1})	B1
	Time for B to get to the 2nd collision $= \frac{3}{\frac{23}{9}}+\frac{d}{\frac{23}{18}}$	M1 A1
	Time for A to get to the 2nd collision $= \frac{3-d}{\frac{17}{9}}$	A1
	Equate times to give equation in d *only*: $\frac{3}{\frac{23}{9}}+\frac{d}{\frac{23}{18}}=\frac{3-d}{\frac{17}{9}}$	M1A1
	$d=\frac{6}{19}$ (0.32 or better)	A1 (7)

Question Number	Scheme	Marks
Alt 7b	Speed of B after hitting wall $= \frac{23}{18}$ (m s^{-1})	B1
	Time for B to reach wall $= \frac{3}{\frac{23}{9}}$	M1
	Dist travelled by A in this time $= \frac{17}{9} \times \frac{3}{\frac{23}{9}} = \frac{51}{23}$ (m)	A1
	Dist between A and B now $= 3 - \frac{51}{23} = \frac{18}{23}$ (m)	A1
	Gap closing at $\frac{23}{18} + \frac{17}{9} = \frac{19}{6}$ (m s^{-1})	
	Time to meet $= \frac{18}{23} \div \frac{19}{6} = \frac{18}{23} \times \frac{6}{19}$	M1A1
	$d = (\frac{18}{23} \times \frac{6}{19}) \times \frac{23}{18} = \frac{6}{19} = 0.32$ (or better)	A1 (7)
		[14]
	Notes	
7a	First M1 for momentum equn with correct terms, condone sign errors, consistent extra g's or missing m's First A1 for a correct equation in v and w *only* Second M1 for Impact Law, correct way up, condone sign errors Second A1 for a correct equation in v and w *only* Third M1 for solving for w Third A1 for $w = 23/9$ **Given answer** Fourth A1 for $v = 17/9$ Accept 1.9 or better **N.B. Treat this as a B1**, dependent on scoring the first 4 marks.	
7b	First B1 for 23/18 seen Accept 1.3 or better First M1 for attempt at a complete expression, in d only, for time for B to arrive at 2nd collision, must be $(\frac{3}{\frac{23}{9}} + \frac{d}{\frac{23}{18}})$ First A1 for a correct expression Second A1 for time for A to get to collision $\frac{3 - d}{\frac{17}{9}}$ Second M1 for equating the times; must be 3 terms Third A1 for a correct equation Fourth A1 for $d = 6/19$ oe or 0.32 or better	
Alt 7b	First B1 for (-)23/18 seen Accept 1.3 or better First M1 for $\frac{3}{\frac{23}{9}}$ which is time for B to reach wall. Allow if they try to divide or the division is implied even if it is done incorrectly. First A1 for 51/23 oe and accept 2.2 or better Second A1 for (3 – 51/23) oe and accept 0.8 or better. Second M1 for time to meet = (a calculated 'separation distance' / ($^{23}/_{18}$ + their v)) Third A1 for a correct time (108/437 oe) accept 0.25 or better	

Question Number	Scheme	Marks
	Fourth A1 for d = 6/19 oe or 0.32 or better	
	Final 3 marks using a ratio approach:	
	Second M1 for attempt at $\frac{\frac{23}{18}}{\text{their } v} = \frac{d}{(\frac{18}{23} - d)}$ correct way up Third A1 for a correct equation Fourth A1 for d = 6/19 oe or 0.32 or better	

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