edexcel

Mark Scheme (Results)

Summer 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:

'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

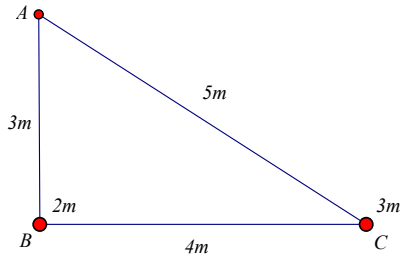
  PCLM Principle of conservation of linear momentum

  RHS, LHS Right hand side, left hand side.

June 2015
WME02 Mechanics 2
Mark Scheme

Question Number	Scheme	Marks
1.	Impulse momentum equation: $-3\mathbf{i}+3\mathbf{j}=0.3\mathbf{v}-0.3(5\mathbf{i}+3\mathbf{j})$	M1A1
	$\mathbf{v}=-5\mathbf{i}+13\mathbf{j}$	A1
	Change in KE: $\frac{1}{2}\times 0.3\times\left((25+169)-(25+9)\right)$ their **v**	M1**A1 ft**
	= 24 J (Accept - 24)	A1
		(6)
	Notes	
	First M1 for attempt at imp-mom equation, with a difference of momenta First A1 for a correct equation Second A1 for -5**i** + 13**j** Second M1 for difference in KE terms in either order (M0 if working in vectors) Third A1 **ft** on their **v**, for a correct expression Fourth A1 for 24 or – 24 or 24.0 etc	

Question Number	Scheme	Marks
2a	Moving parallel to **i** when $t^3 = 8$, $t = 2$	B1
	Differentiate: $\mathbf{a} = -6t\mathbf{i} - 3t^2\mathbf{j}$	M1A1
	Substitute their t (>0) and use Pythagoras: $\lvert\mathbf{a}\rvert = \lvert -12\mathbf{i} - 12\mathbf{j}\rvert = 12\sqrt{2} = 17.0\ (\text{ms}^{-2})$	M1 A1
		(5)
2b	Integrate: $\mathbf{r} = \left(27t - t^3\right)\mathbf{i} + \left(8t - \frac{1}{4}t^4\right)\mathbf{j}(+\mathbf{C})$	M1A1
	Use $t = 1$, $\mathbf{r} = -5\mathbf{i} + 2\mathbf{j}$: $\mathbf{r} = \left(27t - t^3 - 31\right)\mathbf{i} + \left(8t - \frac{1}{4}t^4 - \frac{23}{4}\right)\mathbf{j}$	M1A1
	$t = 3$, $\mathbf{r} = 23\mathbf{i} - 2\mathbf{j}$	A1
		(5)
		[10]
	Notes	
2(a)	B1 for $t = 2$ First M1 for attempt to differentiate (at least one power decreasing by 1) and **i** and **j** included First A1 for correct expression Second M1 for putting their t ($\neq 0$) value in their vector **a,** which must contain **i**'s and **j**'s, AND using Pythag with sq root Second A1 for $\sqrt{288}$ or 17 or better	
2(b)	First M1 for attempt to integrate (at least one power increasing by 1) and **i** and **j** included First A1 for correct expression with or without **C** Second M1 for using $t = 1$ and **-5i + 2j**, in their vector **r** to obtain a complete vector expression for **r** at time t Second A1 for a correct expression (**i**'s and **j**'s do not need to be collected) Third A1 for **23i – 2j.**	

Question Number	Scheme	Marks
3		
	Total mass $17m$	B1
	Moments about AB: $4m\times 2a+5m\times 2a+3m\times 4a=17m\bar{x}$	M1A1
	$\bar{x}=\frac{30}{17}a$	A1
	Moments about BC: $3m\times 1.5a+5m\times 1.5a=17m\bar{y}$	M1A1
	$\bar{y}=\frac{12}{17}a$	A1
	$\tan\theta=\frac{\bar{x}}{3a-\bar{y}}$ for their $\bar{x}$, $\bar{y}$	M1**A1ft**
	$\theta=37.6°$, $(38°)$	A1
		[10]
	Notes	
3.	B1 for total mass $17m$ First M1 for a 'moments' equation about AB or another line, with correct no. of terms , for wire AND masses First A1 for a correct equation (allow consistent omission of m's and/or a's and interchange of a's and m's) Second A1 for $30a/17$, $1.8a$ or better oe for their axis (allow omission of a) Second M1 for a 'moments' equation about AB or another line , with correct no. of terms, for wire AND masses Third A1 for a correct equation (allow consistent omission of m's and/or a's and interchange of a's and m's) Fourth A1 for $12a/17$, $0.71a$ or better oe for their axis (allow omission of a) Third M1 independent for $\tan\theta=\frac{\bar{x}}{3a-\bar{y}}$ or its reciprocal (or their equivalents if they have used different axes). Allow omission of a, if their $\bar{x}$ and $\bar{y}$ are numbers and $\bar{x}$ and $\bar{y}$ do not need to be substituted (they may not have an $\bar{x}$ and $\bar{y}$) Fifth A1 **ft** on their $\bar{x}$ and $\bar{y}$ Sixth A1 for 38° or better (37.5685..) **N.B.** The first two M marks are for a complete method in each case so if they only find the CM of the wire e.g. $(1.5a, a)$ or only find the CM of the particle system e.g. $(2.4a, 0)$, it's **M0**. However, if they do then	

Question Number	Scheme	Marks
	combine, the A1 is for all the equations that they use.	
	N.B. They may take A as their origin. Then $\overline{x}$ is 30/17, $\overline{y}$ = 39/17	
	and $\tan\theta = \overline{x}/\overline{y}$	
	N.B. If they take the CM of the wire (12m) only, to be at the centroid of triangle ABC, (4a/3, a), and then combine with the masses, can score max B1M0M0M1A1ftA0. Beware! Since the CM of the wire only, is (1.5a, a), they will get a correct answer for $\overline{y}$ using this incorrect method. Similarly, if they take the CM of the wire (12m) to be at some other point, with no working , often at (2a, 1.5a), and then combine with the masses, can score max B1M0M0M1A1ftA0.	

Question Number	Scheme	Marks
4a	Normal reaction $6.5g\cos\theta\left(=6.5g\times\frac{12}{13}=6g\right)$	B1
	Use of $F=\mu R$ $\quad F=\frac{1}{3}\times 6.5g\times\frac{12}{13}=2g$	M1
	Work-energy principle: $\frac{6.5}{2}\times 36=6.5g\sin\theta\times d+F\times d$	M1 **A2 ft**
	Substitute and solve for d: $117=dg\left(6.5\times\frac{5}{13}+2\right)$	**DM1**
	$d=\frac{117}{4.5g}=2.7$ m to 2 s.f. **GIVEN ANSWER**	A1 (7)
4b	$\frac{6.5}{2}\times 6^2-\frac{6.5}{2}\times v^2=2Fd$	M1 A2
	$v=2$ m s^{-1}, 2.0 , 2.00	A1 (4)
4balt1	Energy: $\frac{6.5}{2}\times v^2=6.5g\sin\theta\times d-Fd$	M1 A2
	$v=2$ m s^{-1}, 2.0 , 2.00	A1 (4)
4balt2	*F=ma* & *suvat*:	M1
	$6.5g\sin\theta-F=6.5a$	A1
	$v^2=2$ x (g/13 oe) x d	A1
	$v=2$ m s^{-1}, 2.0 , 2.00	A1 (4)
	Notes	
4a	B1 for 6.5gcosθ (This could be scored in (b) if not seen in (a)) First M1 for F = 1/3 x their R (This could be scored in (b) if not seen in (a)) Second M1 for work-energy equation: Need KE, PE (k x $d$sinθ) and WD (n x d) terms First and second A marks **ft** on their F , -1 each error Third M1 **dependent** on second M1, for solving for d. Third A1 for 2.7 (2 SF) **GIVEN ANSWER.** Must finish with 2.7 but (2SF) may be omitted. **N.B.** No marks for a non-energy method.	
4b	M1 for work-energy equation: Need 2 KE terms and 2 x WD (n x d) terms First A2 -1 each error Third A1 for 2 m s^{-1}. Penalise inaccurate answers e.g. 2.01 or 2.02 **Alt 1** M1 for work-energy equation: Need KE, PE (k x $d$sinθ) and WD (n x d) terms First A2 -1 each error	

Question Number	Scheme	Marks
	Third A1 for 2 m s^{-1} .Penalise inaccurate answers e.g. 2.01 or 2.02 **Alt 2** M1 for a complete method ($F = ma$ and $v^2=u^2+2as$) First A1 for $F = ma$, equation in a only Second A1 for $v^2 = 2$ x (g/13 oe) x d (i.e. a must be correct) Third A1 for 2 m s^{-1} Penalise inaccurate answers e.g. 2.01 or 2.02	

Question Number	Scheme	Marks
5a	CLM: $3mu = 3mv + 4mw$	M1A1
	Impact law: $w - v = \frac{1}{3}u$	M1A1
	Solve for w: $w = \frac{4}{7}u$	M1A1
	Impulse $= 4m \times \frac{4u}{7} = \frac{16}{7}mu$ ***Given answer***	A1
	N.B. Given answer, so working needs checking	(7)
5b	$\frac{1}{2} \times 5m \times y^2 = \frac{72}{245}mu^2$	B1
	CLM: $\frac{16}{7}mu = 4mx + 5my$	M1 A1
	Impact: $y - x = e \times \frac{4}{7}u$	M1A1
	$e = \frac{7u}{35} \times \frac{7}{4u} = \frac{7}{20}$	A1
		(6)
	Notes	[13]
5a	First M1 for CLM, correct no. of terms, allow cancelled m's First A1 for a correct equation Second M1 for Impact Law, correct way up Second A1 for a correct consistent equation Third M1 for solving for either v or w Third A1 for either v or w in terms of u ($w = \frac{4}{7}u$ or $v = \frac{5}{21}u$) Fourth A1 for **given answer** fully justified. ($I = 4m.\frac{4}{7}u$ or $-I = 3m(\frac{5}{21}u - u)$)	
5b	B1 for $\frac{1}{2}5my^2 = \frac{72}{245}mu^2$ their y First M1 for CLM, condone sign errors First A1 for $4m.4u/7 = 4mx + 5my$ their x and y Second M1 for Impact Law, correct way up (consistent signs) Second A1 for $e.\ 4u/7 = -x + y$ their x and y	

Question Number	Scheme	Marks
	Third A1 for $e = 7/20$ oe $x = \frac{1}{7}u$ $y = \frac{12}{35}u$ **N.B.** $y = \frac{16}{63}u(1+e)$ $e^2 + 2e - \frac{329}{400} = 0$ $(e + \frac{47}{20})(e - \frac{7}{20}) = 0$	

Question Number	Scheme	Marks
6a	Smooth peg – no friction, so just the normal reaction	B1 (1)
6b	Moments about A: $3aN = W \times 2a \times \cos\alpha + kW \times 4a \times \cos\alpha$	M1 A2
	$N = \frac{W}{3\sqrt{10}}(6+12k) = \frac{\sqrt{10}}{5}W(1+2k)$ ***Given Answer***	A1 (4)
6c	Use of $F \le \frac{3}{4}R$	M1
	Resolve horizontally: $F = N\sin\alpha$	M1A1
	Resolve vertically: $R + N\cos\alpha = W(1+k)$	M1A1
	Sub into $F \le \frac{3}{4}R$	
	$\frac{\sqrt{10}}{5}W(1+2k)\ \frac{1}{\sqrt{10}} \le \frac{3}{4}(W(1+k) - \frac{\sqrt{10}}{5}W(1+2k)\ \frac{3}{\sqrt{10}})$	**DM1**
	$k \le \frac{2}{11}$ ***Given Answer**	A1
		(7)
	Notes	
6a	B1 for smooth peg so no friction so just normal reaction	
6b	M1 for moments about A (or any other complete method) First A2 for an equation in N only, -1 each error Third A1 for the **given answer.** A0 if they go from decimals to surd form	
6c	First M1 for use of $F \le ¾ R$ or $F = ¾ R$ (Allow μ instead of ¾) Second M1 for resolving horizontally or another moments equation First A1 for a correct equation Third M1 for resolving vertically or another moments equation Second A1 for a correct equation Fourth M1 dependent on all 3 previous M's for producing an equation or inequality in k only. Third A1 for $k \le 2/11$ **given answer (must have worked with an inequality all the way through to earn this mark)**	

Question Number	Scheme	Marks
7a	Vertical speed = 0: $v = 9 - gt = 0$	M1
	$t = \frac{9}{g} = 0.92$ (s) 0.918	A1
		(2)
7b	$x = 4t, y = 9t - \frac{1}{2}gt^2$	B1, B1
	Use $y = x(= k)$: $4t = 9t - \frac{1}{2}gt^2$	M1
	$k = \frac{40}{g} = 4.1$ (4.08)	A1 (4)
7c	Complete method using symmetry of times to find other pt : Time to $A = k/4 = 10/g$ => time to other pt = 9/g – (10/g - 9/g)= 8/g So x = 4 x 8/g	M1
	$x = 4k/5$ or (72/g – k) or (7.3(5) – k)	A1
	$\mathbf{r} = \left(\frac{4}{5}k\right)\mathbf{i} + k\mathbf{j}$	A1 (3)
7c(alt)	Complete method using symmetry of horiz distances to find other pt : At max ht , x = 4 x 9/g = 36/g => At other pt, x = 36/g – (k - 36/g)	M1
	Other point: : $x = 4k/5$ or (72/g – k) or (7.3(5) – k)	A1
	$\mathbf{r} = \left(\frac{4}{5}k\right)\mathbf{i} + k\mathbf{j}$	A1
		(3)
7c(alt)	Same height: $\frac{40}{g} = 9t - \frac{1}{2}t^2$	M1
	Other point: : $x = 4k/5$ or (72/g – k) or (7.3(5) – k)	A1
	$\mathbf{r} = \left(\frac{4}{5}k\right)\mathbf{i} + k\mathbf{j}$	A1
		(3)
	NB: an answer of $\mathbf{r} = 3.3\mathbf{i} + 4.1\mathbf{j}$ or $\mathbf{r} = \frac{32}{g}\mathbf{i} + \frac{40}{g}\mathbf{j}$ scores M1A1A0	

7d	$4\mathbf{i} + k\mathbf{j}$ perpendicular to $4\mathbf{i} + 9\mathbf{j}$: $\frac{4}{k} = -\frac{9}{4}$, $k = -\frac{16}{9}$	M1A1
	$-\frac{16}{9} = 9 - gT$, $T = \frac{97}{9g} = 1.1$ (1.10)	M1A1
		(4)
7d	**OR**: vert: $v = 9 - gT$ AND combine with the horiz cpt.	M1
	$\mathbf{v} = 4\mathbf{i} + (9 - gT)\mathbf{j}$	A1
	$\frac{4}{9 - gT} = -\frac{9}{4}$	M1
	$T = \frac{97}{9g} = 1.1$ (1.10)	A1 (4)
	Notes	
7a	M1 for $0 = 9 - gt$ (or any other complete method) condone sign errors A1 for $9/g$ or 0.918 or 0.92 (correctly obtained) (45/49 is A0)	
7b	First B1 for $k = 4t$ Second B1 for $k = 9t - \frac{1}{2} gt^2$ M1 for eliminating and solving for k or t A1 for $k = 40/g$ or 4.08 or 4.1	
7c	M1 for a complete method using symmetry on times First A1 for $x = \frac{4}{5} k$ Second A1 for $\frac{4}{5} k\,\mathbf{i} + k\,\mathbf{j}$ **OR** M1 for a complete method using symmetry on horiz. distances First A1 for $x = \frac{4}{5} k$ Second A1 for $\frac{4}{5}\,\mathbf{i} + k\,\mathbf{j}$ **OR** M1 for $k = 9t - \frac{1}{2} gt^2$ First A1 for $x = \frac{4}{5} k$ Second A1 for $\frac{4}{5} k\,\mathbf{i} + k\,\mathbf{j}$ **N.B. Correct answers not in terms of k, score M1A1A0**	
7d	First M1 for attempt to find a vector of form $(4\mathbf{i} + k\mathbf{j})$ which is perp^{ar} to $4\mathbf{i} + 9\mathbf{j}$ (must use reciprocal, but condone missing – sign) First A1 for $k = -\frac{16}{9}$ Second M1 for an equation in T only $(-\frac{16}{9} = 9 - gT)$ Second A1 for $T = 97/(9g)$ or 1.10 or 1.1 **OR** First M1 for attempt to find velocity vector at time T First A1 for $4\mathbf{i} + (9 - gT)\mathbf{j}$ **–** This may not be explicit but they must have **BOTH cpts.** Second M1 for using the perpendicularity with $4\mathbf{i} + 9\mathbf{j}$ to form an	

	equation in T only (must use reciprocal, but condone missing – sign) Second A1 for $T = 97/(9g)$ or 1.10 or 1.1 **N.B.** $-9 = 9 - gT$ ($T = 1.84$) is M0A0M0A0	

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