Mark Scheme (Results)

Summer 2017

Pearson Edexcel International A Level
In Mechanics M2 (WME02) Paper 1

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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 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 √ 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.

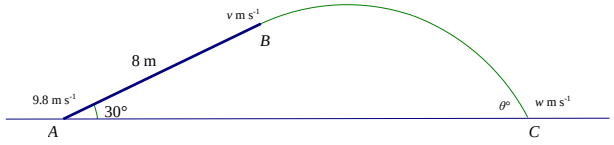
  N.B. Over-accuracy or under-accuracy of correct answers should only be penalised *once* per complete question. However, premature approximation should be penalised every time it occurs.
- Marks must be entered in the same order as they appear on the mark scheme.
- In all cases, if the candidate clearly 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
1	Impulse-momentum principle: $(7\mathbf{i}-5\mathbf{j})=4\mathbf{v}-4(2\mathbf{i}+3\mathbf{j})$	M1A1
	$\left(\mathbf{v}=\frac{15}{4}\mathbf{i}+\frac{7}{4}\mathbf{j}\right)$	A1
	$\lvert\mathbf{v}\rvert=\frac{1}{4}\sqrt{15^2+7^2}$	M1
	$=\frac{1}{4}\sqrt{274}=4.1\,(\text{m s}^{-1})$ (or better)	A1 cso
		(5)
		[5]
	Notes	
	First M1 for use of Impulse-Momentum principle, dim correct, correct no. of terms and must be a *difference* of momenta. First A1 for a correct equation Second A1 for correct velocity vector Second M1 for attempt to find magnitude of their **v** Third A1 cso for an exact answer or 4.1 or better	
2a	Use of $P = Fv$: $280 = F \times 2$ oe	M1
	Equation of motion: $F-75g\sin\theta=R$	M1 A1
	$140-75\times9.8\times\frac{1}{21}=R$	
	$R=105$ (or 110)	A1
		(4)
	Notes	
	First M1 for $280 = F \times 2$ oe Second M1 for resolving parallel to the plane with $a = 0$ with usual rules	
	First A1 for a correct equation as shown	
	Second A1 for 105 or 110	
2b	Equation of motion: $75g\sin\theta+\frac{280}{3.5}-60=75a$ or $-75a$	M1A2
	$a=0.73$ (m s^{-2}) (0.733) or – 0.73 (- 0.733)	A1
		(4)
		[8]
	Notes	
	First M1 for resolving parallel to the plane with $a \neq 0$ with usual rules First A1and Second A1 for a correct equation. Deduct 1 mark for each incorrect term. (A1A0 or A0A0) (Use of 280/2 is an A error) Third A1 for 0.73 or 0.733 (allow negative answers)	
3a	Integrate: $v=\int(4t-8)\,\mathrm{d}t=2t^2-8t\,(+C)$	M1

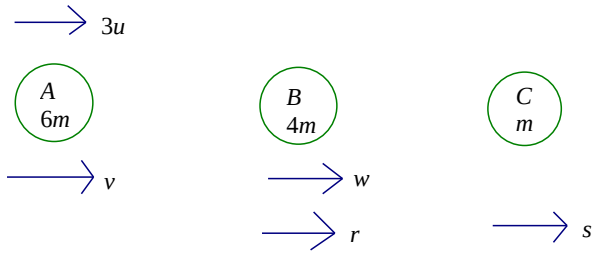
Question Number	Scheme	Marks
	Use $t=0, v=6$: $v=2t^2-8t+6$	M1A1
	Use factor theorem or factorise: $v=2(t-1)(t-3)$ $\Rightarrow$ at rest for $t=1$	M1
	Second value $t=3$	A1
	Alternative: verify that $v=0$ when $t=1$ then find second solution.	(5)
	Notes	
	First M1 for attempt to integrate, at least one power increasing Second M1 for using initial conditions to find an expression for *v* First A1 for a correct expression for *v* Third M1 for showing that *v* = 0 when *t* = 1 Second A1 for *t* =3 **(N.B. this is actually B1 mark)** *but must come from a correct v.*	
3b	Integrate to find distance: $s=\int v\mathrm{d}t=\frac{2}{3}t^3-4t^2+Ct$ Follow their $C\neq 0$	M1**A1 ft**
	Correct strategy: $\left\lvert\left[\frac{2}{3}t^3-4t^2+Ct\right]_1^3\right\rvert+\left[\frac{2}{3}t^3-4t^2+Ct\right]_3^4$	M1
	$-\left(0-\frac{8}{3}\right)+\left(\frac{8}{3}-0\right)=\frac{16}{3}$ (m) (5.33)	A1 (4)
	Notes	
	First M1 for attempt to integrate their *v* (M0 if they integrate a multiple of their *v*), at least one power increasing First A1 ft on their *v* (but must include a non-zero *C*) Second M1 (independent) for a complete method to find the total distance Second A1 for 16/3 or 5.3 or better **N.B.** If they consider $0 < t < 4$ instead of $1 < t < 4$, then treat as a MR and they can score the second M1, if they use a correct strategy for (0,4).	

Question Number	Scheme	Marks
4a	Moments about A: $0.5\times 2g + 2\times 5g\,(=11g) = T\cos\theta\times 4 = T\times\frac{3}{5}\times 4$	M1A2
	$T = 11g\times\frac{5}{12} = \frac{55}{12}g = 44.9$ (45) (N)	A1 (4)
	Notes	
	N.B. If all g's are missing, mark as a MR. M1 for M(A), with usual rules First A1 and second A1 for a correct equation in T only i.e. must be using a correct angle (but value of trig ratio not needed at this stage) Deduct 1 mark for each incorrect term. (A1A0 or A0A0) Third A1 for 45 or 44.9 (N) (A0 for 45.0)	
4b	Resolving: $\leftrightarrow H = T\sin\theta$ **OR** M(D), $H\times 3 = 2g\times 0.5 + 5g\times 2$	M1
	$\updownarrow T\cos\theta + V = 7g$ **OR** M(B), $V\times 4 = 2g\times 3.5 + 5g\times 2$	M1A1
	Pythagoras: $\lvert R\rvert = \sqrt{41.65^2 + 35.93^2} = 55.0$ (55) (N)	M1A1 (5)
	Notes	
	First M1 for resolving horizontally or M(D) with usual rules to give equation in T only. (T does not need to be substituted) Second M1 for resolving vertically or M(B) with usual rules First A1 for a correct equation in T only. (T does not need to be substituted) Third M1 (independent but must have found 2 components) for squaring, adding and rooting their 2 components Second A1 for 55 or 55.0	
4c	Use of $F \le F_{\max} = \mu R$: $V \le \mu H$ (Must have found H and V)	M1
	m^3 $\frac{V}{H} = \frac{41.65}{35.93..} = \frac{51}{44}$, 1.2 or better.	A1 (2)
	Notes	
	M1 for use of $V \le \mu H$ M0 for use of $V = H$ or $V < H$ m^3 $\frac{V}{H} = \frac{51}{44}$ Allow fraction (since g cancels) or 1.2 or better	

Question Number	Scheme	Marks
		
5a	Energy: $\frac{1}{2}m\times 4.2^2 + mg\times 8\sin 30° = \frac{1}{2}m\times u^2$	M1A2
	$u^2 = 96.04 \Rightarrow u = 9.8$ or 9.80	A1 (4)
	Notes	
	M1 for energy equation with correct no. of terms (M0 if not using energy) First A1 and Second A1 for a correct equation. Deduct 1 mark for each incorrect term. (A1A0 or A0A0) Third A1 for u = 9.8 or 9.80 (49/5 is A0 because of rubric on qu paper)	
5b (i) **5b(ii)**	Their u or 9.8 $\tan\theta° = \frac{w_V}{w_H}$ or $\cos\theta° = \frac{w_H}{w}$ or $\sin\theta° = \frac{w_V}{w}$ where $w_H = 4.2\cos 30°$; $w_V = \sqrt{(4.2\sin 30)^2 + 2g\times 4}$; $w =$ their u $\theta = 68$ or 68.2	**B1 ft** M1 **A1 ft** A1
	Notes	(4)
	B1 **ft** for w = their u or if they use energy again w = 9.8 (Do not award if it has come from use of $v^2 = u^2 + 2as$, without components, for a projectile, or any other incorrect method) M1 for a complete method to produce an equation in θ only, **ft** on their u value (**Allow** an inverted tan or cos/sin confusion) (M0 if they use u = 0 when finding w_V or don't resolve 4.2) First A1 **ft** for a correct equation in θ only, **ft** on their u or w value Second A1 for $\theta = 68$ or 68.2	
5c	**Find *t***	

<table>
<tr><th>Question Number</th><th>Scheme</th><th>Marks</th></tr>
<tr><td></td><td>Either:
Vertical component of velocity at C: $4.2\sin 30° - gt = -w\sin\theta°$
Follow their w, θ</td><td>M1A1</td></tr>
<tr><td></td><td>$t = 1.14$ (s) (8/7)</td><td>A1</td></tr>
<tr><td></td><td>Or:
Using vertical distance B to ground: $-4 = 4.2\sin 30° \times t - \frac{1}{2}gt^2$</td><td>M1 A1</td></tr>
<tr><td></td><td>$t = 1.14$ (s) (8/7)</td><td>A1</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td></td><td><u>Use horizontal motion:</u>
Either : $4.2\cos 30° \times t$</td><td>M1</td></tr>
<tr><td></td><td>$= 4.16$ (4.2) (m)</td><td>A1</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td></td><td>Or: (their u or w)cos(their q) ´ t</td><td>M1</td></tr>
<tr><td></td><td>$= 4.16$ (4.2) (m)</td><td>A1 (5)</td></tr>
<tr><td></td><td></td><td>[13]</td></tr>
<tr><td></td><td>Notes</td><td></td></tr>
<tr><td></td><td>First M1 for a complete method to find the time with usual rules
First A1 for a correct equation for their w and q
Second A1 for t = 1.14 or better
Second M1 for horizontal motion equation with usual rules
Third A1 for 4.2 or 4.16 (m)</td><td></td></tr>
<tr><td>6a</td><td>
<table>
<tr><td></td><td>Area</td><td>c of m to AB</td><td>(c of m to AE)</td></tr>
<tr><td>Square</td><td></td><td>$36a^2$ $3a$</td><td>$(3a)$</td></tr>
<tr><td>Triangle</td><td>$9a^2$</td><td>$5a$</td><td>$(2a)$</td></tr>
<tr><td>L</td><td>$27a^2$</td><td>$\bar{x}$</td><td>$(\bar{y})$</td></tr>
</table>
</td><td></td></tr>
<tr><td></td><td>Ratio of areas: $4 : 1 : 3$ oe OR $2 : 1 : 3$</td><td>B1</td></tr>
<tr><td></td><td>Distances to AB: $3a : 5a : \bar{x}$ $1.5a : 4a : \bar{x}$</td><td>B1</td></tr>
<tr><td></td><td>About AB: $4 \times 3a - 1 \times 5a = 3\bar{x}$ $2 \times 1.5a + 1 \times 4a = 3\bar{x}$</td><td>M1A1</td></tr>
<tr><td></td><td>$\bar{x} = \frac{7}{3}a$ Given Answer</td><td>A1 (5)</td></tr>
<tr><td></td><td>Notes</td><td></td></tr>
<tr><td></td><td>First B1 for any correct mass ratios
Second B1 for correct distances to AB
M1 for moments equation (about any line parallel to AB)
First A1 for a correct equation
Second A1 for correct given answer (correctly obtained)</td><td></td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td>6b</td><td>About AE: $4 \times 3a - 1 \times 2a = 3\bar{y}$ OR $2 \times 3a + 1 \times 4a = 3\bar{y}$</td><td>M1A1</td></tr>
</table>

Question Number	Scheme	Marks
	$\bar{y} = \frac{10}{3}a$ oe	A1 (3)
	Notes	
	M1 for moments equation (about any line parallel to *AE*) First A1 for a correct equation Second A1 for $\frac{10}{3}a$ oe (Must be positive)	
6c	Use position of c of m of combined system: From *AB*: $\dfrac{\frac{7}{3}a \times M + 3a \times kM}{M(1+k)}$	M1 A1
	From *AE*: $\dfrac{\frac{10}{3}a \times M}{M(1+k)}$ **OR** From *BC*: $\dfrac{\frac{8aM}{3} + 6akM}{M(1+k)}$	A1
	AC vertical $\Rightarrow \frac{7}{3}aM + 3akM = \frac{10}{3}aM \quad \left(\frac{7}{3} + 3k = \frac{10}{3}\right)$	**DM1**
	$k = \frac{1}{3}$ (0.33)	A1 (5)
6c	**Notes** First M1 for attempt at complete method to find *either* coordinate of the cm of combined system **(M0 if they combine masses with areas**) First A1 for a correct moments equation (with distances measured from a line parallel to *AB*) Second A1 for a correct moments equation (with distances measured from a line parallel to *AE*) Second M1, dependent on first M1, for setting $\bar{x} = \bar{y}$ (or an appropriate equation e.g $\bar{y} = 6a - \bar{x}$) Must have a new $\bar{x}$ AND a new $\bar{y}$, *and solving for k.* Third A1 for *k* = 1/3 or 0.33 or better	

Question Number	Scheme	Marks
6c	**Alternative:** Moments about A	
	$\sqrt{(\bar{x}^2+\bar{y}^2)}a\sin(45-a)'\ \ M=3a\cos 45'\ \ kM$	M1A1A1
	N.B. $(\bar{y}-\bar{x})\cos 45'\ \ M=3a\cos 45'\ \ kM$	
	Find a (if needed) and solve for k	**DM1**
	$k=\frac{1}{3}$ (0.33)	A1 (5)
	Notes First M1 for clear attempt at moments about A – requires both terms and dimensionally correct (with or without a's and/or g's) and resolving on both sides First A1 for RHS in terms of M, a and k only (a may have cancelled) Second A1 for LHS in terms of M, a, a, $\bar{x}$ and $\bar{y}$ (a may have cancelled) For **N.B.** cos 45 may have cancelled Second DM1, dependent on first M1, for finding the value of a (if needed*) and solving for k* . **N.B.** M0 if 45 has been replaced with some other angle e.g. 30 or 60. Third A1 for $k=\frac{1}{3}$ (0.33)	
7a		
	CLM: $6m\times 3u=6mv+4mw$	M1A1
	Impact law: $\frac{1}{6}'\ 3u=-v+w$	M1A1
	Solve for w: e.g. $18u=6v+4w$ $3u=6w-6v \Rightarrow 21u=10w$, $w=\frac{21}{10}u$ **Answer Given**	**DM1**A1 cso (6)
	Notes	
	First M1 for CLM with correct no. of terms with correct masses correctly matched with velocities, but condone sign errors and allow consistent omission of m's (note that w is defined but v is not) First A1 for a correct equation Second M1 for NIL with 1/6 on correct side of equation Second A1 for a correct consistent equation Third **DM**1, dependent on both M's, for solving for w Third A1 for correct **given** answer ($w = 2.1u$ is A0)	
	N.B. Ignore diagram if it helps the candidate.	
7b	(v =) $1.6u$ or $-1.6u$	B1

Question Number	Scheme	Marks
	KE loss = $\frac{1}{2}\times 6m\times 9u^2 - \left(\frac{1}{2}\times 6m\times 1.6^2u^2 + \frac{1}{2}\times 4m\times 2.1^2u^2\right)$	M1A1
	Fraction of KE lost = $\frac{10.5mu^2}{27mu^2} = \frac{7}{18}$, 0.39 or better	M1A1
		(5)
	Notes	
	B1 for $1.6u$ or $-1.6u$ First M1 for ±(initial KE – sum of final KE terms), with masses and velocities correctly matched up. First A1 for a correct expression for the LOSS (if they get a negative correct answer, allow this to be changed to a positive one for the A1) Second M1 for Loss/Initial Second A1 for 7/18, 0.39 or better	
7c	$8.4mu = 4mr + ms$ $2.1ue = -r + s$ $r = \frac{2.1u}{5}(4 - e)$	M1A1
	Use $r \geq 1.6u$: $\frac{2.1u}{5}(4 - e) \geq 1.6u$ (their v)	**DM1**
	$0 \leq e \leq \frac{4}{21}$ (0.190) (0.19)	**DM1** A1
		(5)
		[16]
	Notes	
	First M1 for a complete method to find r First A1 for a correct expression in terms of u and e only Second M1, dependent on first, for their $r \geq 1.6u$ (their v) oe Third M1, dependent on the second M1, for producing $e \leq k$, where k is a number. Third A1 for $0 \leq e \leq 4/21 = 0.19$ or better **N.B. If they use $r > 1.6u$ oe, final two M marks can be scored.**	