Mark Scheme (Results)

January 2021

Pearson Edexcel International Advanced Level In Mechanics M2 (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.

- 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.

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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)

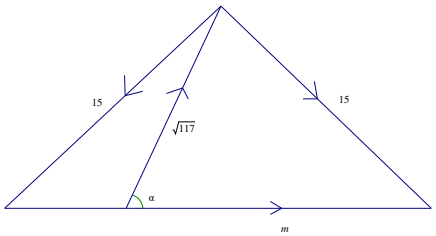
  NEL Newton's Experimental Law (Newton's Law of Impact)

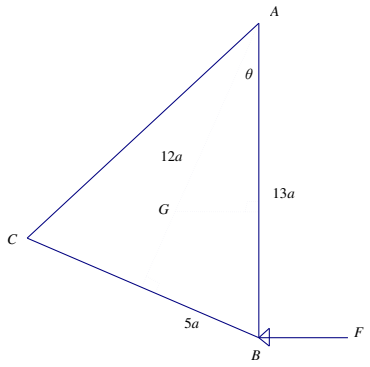
  HL Hooke's Law

  SHM Simple harmonic motion

  PCLM Principle of conservation of linear momentum

  RHS, LHS Right hand side, left hand side.

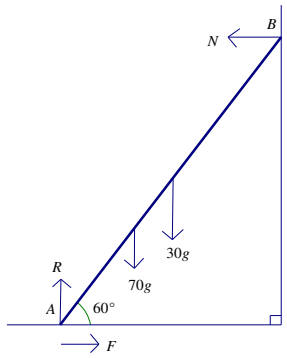
Question Number	Scheme	Marks	
1	$(\mathbf{I}=)1.5\{v\mathbf{i}-(4\mathbf{i}+6\mathbf{j})\}$	M1	Use of $\mathbf{I}=m\mathbf{v}-m\mathbf{u}$. Must be using $v\mathbf{i}$. Condone **u**, **v** confusion. Ignore the left hand side
	$=1.5\{(v-4)\mathbf{i}-6\mathbf{j}\}$	A1	Or equivalent seen or implied Condone subtraction the wrong way round. Ignore the left hand side
	$\Rightarrow 15^2=1.5^2\{(v-4)^2+6^2\}$	M1	Use of modulus. Allow for $p^2+q^2=100$
	$(100=(v-4)^2+36)$	A1	Correct unsimplified equation in v
	$(v^2-8v-48=0)$	A1	Correct simplified equation in v seen or implied.
	$\Rightarrow v=12$	A1	One correct value
	or $v=-4$	A1	Both correct values
		[7]	
1 alt1			
	Initial momentum $=(6\mathbf{i}+9\mathbf{j})$ Ns	M1	Impulse momentum triangle. Accept $\sqrt{117}$ Ns
	$\cos\alpha=\frac{6}{\sqrt{117}}\left(=\frac{2}{\sqrt{13}}\right)$	A1	Or equivalent
	$m^2+117-2m\sqrt{117}\cos\alpha=225$	M1	Use of cosine formula (final momentum m)
	$m^2-12m-108=0$	A1	Or equivalent
	$\Rightarrow m=-6$ or $m=18$	A1	
	$\Rightarrow v=12$	A1	One correct value
	or $v=-4$	A1	Both correct values
		[7]	
1alt2	Initial momentum $=(6\mathbf{i}+9\mathbf{j})$ Ns	M1	Impulse momentum triangle. Accept $\sqrt{117}$ Ns
	$\sin\alpha=\frac{3}{\sqrt{13}}$	A1	Or equivalent
	$\frac{15}{\sin\alpha}=\frac{\sqrt{117}}{\sin\theta}$	M1	Use of sine formula
	$\Rightarrow \sin\theta=\frac{3}{5}$, $\theta=36.9°$ or $\theta=143.1°$	A1	
	$\frac{m}{\sin 86.8}=\frac{15}{\sin\alpha}$ or $\frac{m}{\sin 19.4}=\frac{15}{\sin(180-\alpha)}$	A1	Correct equation in m
	$\Rightarrow v=12$	A1	One correct value
	or $v=-4$	A1	Both correct values
		[7]	

Question Number	Scheme	Marks	Notes
2.			
	Centre of mass of triangle is at G, where $AG = 8a$	**B1**	Or equivalent. Seen or implied e.g. $\frac{2}{3} \times 5a\cos\theta \left(= \frac{40a}{13} \right)$ from AB
	$\sin\theta = \frac{5}{13}$	**B1**	Or equivalent. Any correct trig ratio for an angle in the triangle. Seen or implied
	M(A): $13aF = W \times 8a \times \frac{5}{13}$	**M1**	Dimensionally correct with resolved component of their $8a$ Condone sin/cos confusion. If g appears, mark as an accuracy error
		A1	Correct substituted equation (any form)
	$F = \frac{40W}{169}\,(\text{N})$	**A1**	$0.24W$ or better
		[5]	

Question Number	Scheme	Marks	Notes
3.	Use of $P = 15F_1$ or $P = 10F_2$	M1	Seen or implied
	$F_1 - R = 600 \times 0.2$	M1	Equation of motion. Needs all terms. Condone sign errors. Inclusion of *g* is an accuracy error
	$\frac{P}{15} - R = 120$	A1	Correct equation in *P* and their *R*
	Up the slope: $F_2 - R - 600g\sin\theta = 0$	M1	Equation of motion. Needs all terms and $F_2 \neq F_1$. Condone sign errors. Condone sin/cos confusion. Omission of *g* is an accuracy error
		A1	Unsimplified equation in *P* or F_2 with at most 1 error
	$\frac{P}{10} - R - 30g = 0$	A1	Correct equation in *P* and their same *R*
	$\frac{P}{15} - \frac{P}{10} + 30g = 120$	DM1	Solve for *P* . Dependent on the 2 preceding M marks
	$P = 5220$ (5200)	A1	Correct max 3 s.f.
		[8]	

Question Number	Scheme	Marks	Notes
4	$6m\times 3a+4m\times 4a+5m\times 2a=15m\times y$	M1	Moments about a horizontal axis. Terms dimensionally consistent. Condone slip with a Needs all terms. Condone sign errors
	$\left(44ma=15my\right)$	A1	Correct unsimplified
	$y=\frac{44a}{15}$ from B	A1	Or equivalent. Correct for their axis $\frac{46a}{15}$ from A $\frac{16a}{15}$ from E (CD)
	$5m\times\frac{3a}{2}+4m\times a=15mx$	M1	Moments about a vertical axis Terms dimensionally consistent. Condone slip with a Needs all terms. Condone sign errors
	$\left(\frac{23ma}{2}=15mx\right)$	A1	Correct unsimplified
	$x=\frac{23a}{30}$ from E (AB)	A1	Or equivalent. Correct for their axis $\frac{67a}{30}$ from C
	$\tan\theta=\frac{\frac{23}{30}}{\frac{44}{15}}$	M1	Find a relevant angle using distances measured from B (Allow for $\tan\theta=\frac{88}{23}$)
	$=\frac{23}{88}\left(=0.261...\right)$	A1ft	Correct for their distances from B. $\left(\frac{\text{horizontal}}{\text{vertical}}\right)$
	$\theta=14.64....\simeq 15°$	A1	From correct working. The question asks for the answer to the nearest degree.
		[9]	
	SR1: If a candidate has not used a in their working at all, marks as a misread. Maximum marks available: M1A0A0 M1A1A1 M1A1A1		
	SR2: If a candidate has a in their working, but not as part of their values for $\bar{x}$ and $\bar{y}$ the maximum marks available are M1A1A0 M1A1A0 M1A1A1		

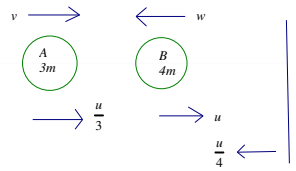
Question Number	Scheme	Marks	Notes
5(a)	$5T^2-12T+15=T^2+8T-10$	M1	Parallel to $\mathbf{i}+\mathbf{j}$
	$\Rightarrow 4T^2-20T+25=0$	A1	Correct quadratic in T
	$\Rightarrow T=\dfrac{5}{2}$	A1	
		[3]	
5(b)	$\mathbf{a}=(10t-12)\mathbf{i}+(2t+8)\mathbf{j}$	M1	Correct differentiation (at least 2 powers going down by one)
	$=18\mathbf{i}+14\mathbf{j}$	A1	
	$\lvert\mathbf{a}\rvert=\sqrt{18^2+14^2}$	DM1	Use of Pythagoras to find magnitude. Dependent on preceding M1
	$=\sqrt{520}=22.8$ (m s^{-2})	A1	23 or better e.g. $2\sqrt{130}$
		[4]	
5(c)	$\mathbf{s}=\left(\dfrac{5}{3}t^3-6t^2+15t\right)\mathbf{i}+\left(\dfrac{1}{3}t^3+4t^2-10t\right)\mathbf{j}$	M1	Integrate (at least 2 powers going up by one)
		A1	At most one error
		A1	All correct
	$=(45-54+45)\mathbf{i}+(9+36-30)\mathbf{j}$		
	$=36\mathbf{i}+15\mathbf{j}$ (m)	A1	
		[4]	
		[11]	

Question Number	Scheme	Marks	Notes
6a			
	M(*A*): $3\times30g\times\frac{1}{2}+70g\times2\times\frac{1}{2}=N\times\frac{6\sqrt{3}}{2}$	M1	All terms required. Must be dimensionally correct. Condone sin/cos confusion and sign errors. Allow with sin/cos 60°
	$\left(45g+70g=3\sqrt{3}N\right)$	A1	Correct unsimplified
	↕: $R=100g$,	B1	B0 if they have $F_B\neq0$
	↔: $F=N=217\,(\text{N})$ $\left(\frac{115g}{3\sqrt{3}}\right)$	B1	Solve for *F* (216.891… seen or implied)
			NB Either of these B marks could be earned for a second moments equation
	$\sqrt{(100g)^2+217^2}$	DM1	Use of Pythagoras with *their R, F* Dependent on the preceding M mark
	$=1000$ (N)	A1	
Alt6a	M(*B*): $30g\times3\cos60°+70g\times4\cos60°$ $=R\times6\cos60°-F\times6\sin60°$ M(base wall) $3R=\frac{3}{2}.30g+2.70g+3\sqrt{3}N$	M1	All terms required. Must be dimensionally correct. Condone sin/cos confusion and sign errors. Allow with sin/cos 60°
	$\left(45g+140g=3R-3\sqrt{3}F\right)$	A1	
	↕: $R=100g$,	B1	
	$3\sqrt{3}F=115g$, $F=\frac{115g}{3\sqrt{3}}$	B1	Solve for *F* 216.891……
	$\sqrt{(100g)^2+217^2}$	DM1	Use of Pythagoras with *their R, F*
	$=1000$ (N)	A1	
		[6]	
6b	$F=0.4\times100g\left(=392\right)$	M1	Use of $F=\mu R$ with their value for *R*
	M(*A*): $F\times3\sqrt{3}=70g\times\frac{x}{2}+30g\times\frac{3}{2}$	M1	$\left(F\neq217\right)$ Allow for moments about *B* to find distance from the top
	$40g\times3\sqrt{3}=35gx+45g$	A1	Equation in *x* (distance from ground) only
	$\left(AD=\right)x=4.65$ (m)	A1	4.7 or better (4.65274….)
		[4]	
6c	e.g. The ladder does not bend The ladder meets the wall/floor at a point The weight acts at a single point	B1	With no incorrect statement(s) seen

		[1]	**[11]**

Question Number	Scheme	Marks	Notes
7a	Equation for conservation of energy.	M1	Need all terms. Condone sign errors
	$\frac{1}{2}\times m\times 144 + m\times g\times 20 = \frac{1}{2}mv^2$	A1 A1	Correct unsimplified equation with at most one error Correct equation (with or without m)
	$v = 23$ or 23.2	A1	Max 3 s.f.
		[4]	
7b	$12\cos\theta\times 5 = 40$	M1	Horizontal motion Condone sine/cosine confusion
	(minimum=) $12\cos\theta = 8$ (m s^{-1})	A1	Final answer : do not ignore subsequent working
		[2]	
7c	Speed = 10 $\Rightarrow$ Vertical component $= 6$ (m s^{-1})	B1ft	Follow their horizontal component
	$(\pm)6 = 12\sin\theta - gt$	M1	Vertical speed
	$= 12\times\frac{\sqrt{5}}{3} - gt$ ($t = 0.30..$ and $t = 1.52..$)	A1	Correct equation for one value of t or for the time interval. Correct trig value seen or implied
	Time = 1.52.. – 0.30.. = 1.22… (s)	A1	Correct interval
	Required time = $5 - 1.22$ (s)	M1	Find required time – follow their 1.22
	$= 3.78$ (s)	A1	Or 3.8. Max 3 s.f.
		[6]	
	Alternatives for M1A1A1		
	Use of $v = u + at$	(M1)	
	$-6 = 6 - gt$	(A1)	Or find time to top and double it
	$t = \frac{12}{g}$	(A1)	
	Vertical speed: $6 = 12\sin\theta - gt_1$	(M1)	
	$-6 = 12\sin\theta - gt_2$	(A1)	
	$12 = g(t_2 - t_1)$, $t_2 - t_1 = \frac{12}{g}$	(A1)	
	Alternatives for B1M1A1A1		
	ht above A $\frac{22}{g}$	(B1)	Using energy 2.24… seen or implied e.g. by 22.24…
	Use of $s = ut + \frac{1}{2}at^2$	(M1)	$20 + \frac{22}{g}$ used with $12\sin\theta$ is M0
	$\frac{22}{g} = 12\sin\theta t - \frac{1}{2}gt^2$	(A1)	
	Time = 1.52.. – 0.30.. = 1.22… (s)	(A1)	Correct interval
	Speed 10, angle to horizontal $\alpha \Rightarrow 10\cos\alpha = 8$	(B1)	
	Time to top: $0 = 10\sin\alpha - gt$	(M1)	
	$10\times 0.6 = gt$	(A1)	

	Total time $= \frac{12}{g}$	(A1)	
		[11]	

Question Number	Scheme	Marks	Notes
8a			
	Impulse on A: $8mu = 3mv - 3m \times \frac{u}{3}$	M1	Terms dimensionally correct. Must be subtracting. Condone sign errors. Must be combining correct mass and speed
	$v = 3u$	A1	
	Impulse on B: $8mu = 4mu + 4mw$	M1	Terms dimensionally correct. Condone sign errors Or use CLM: $9mu - 4mw = 3m\frac{u}{3} + 4mu$ Must be combining correct mass and speed
	$w = u$	A1	
	Impact law: $u - \frac{u}{3} = e(3u + u)$	M1	Used the right way round. Condone sign errors
	$e = \frac{1}{6}$	A1	
	Award first 4 marks in order on the scheme. Marks for CLM equation, if used, should be given in place of whichever impulse equation is not used.		
	Watch out for sign errors in the equations If they have $3mv + 4mw$ in the equation for CLM they might combine this with $w = -u$ to obtain a "correct" answer. The sign error in the CLM is due to a misread so the maximum score for this double sign error is 4/6		
		[6]	
8b	Gap when B hits wall $= \frac{2d}{3}$	B1	Or find distances from the first impact: $s_A = \frac{d}{3} + \frac{u}{3}t$ and $s_B = d - \frac{u}{4}t$
	Speed of rebound from wall $= \frac{u}{4}$	B1	Allow + / -
	Time to close gap $= \frac{\frac{2d}{3}}{\frac{u}{3} + \frac{u}{4}}$	M1	
	$= \frac{8d}{7u}$	A1	
	Distance from wall $= \frac{8d}{7u} \times \frac{u}{4}$	DM1	Dependent on the preceding M1
	$= \frac{2d}{7}$	A1 [6]	
8balt	Time for A $\frac{d-x}{u/3}$ $\left(= \frac{3d-3x}{u}\right)$	B1	
	Speed of rebound from wall $= \frac{u}{4}$	B1	

	Time for $B = \frac{d}{u} + \frac{x}{u/4}$	M1	
	$\left(= \frac{d+4x}{u} \right)$	A1	
	$3d - 3x = d + 4x$	DM1	Solve for x Dependent on the preceding M1
	$x = \frac{2d}{7}$	A1 [6]	
		[12]	

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