Mark Scheme (Results)

Summer 2019

Pearson Edexcel GCSE Mathematics
Mechanics 2 (6678/01)

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Summer 2019
Publications Code 6678_01_1906_MS

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 √ 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. 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.

6. 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.

- 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.

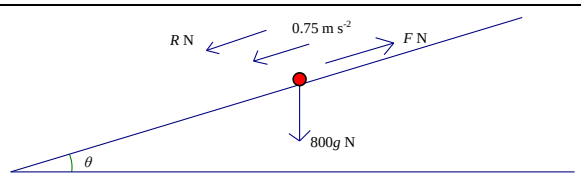
  N2L Newton's Second Law (Equation of Motion)

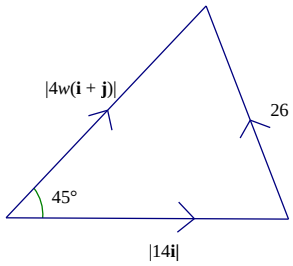
  NEL Newton's Experimental Law (Newton's Law of Impact)

  PCLM Principle of conservation of linear momentum

  RHS, LHS Right hand side, left hand side.

June 2019
Mechanics 2 - 6678
Mark Scheme

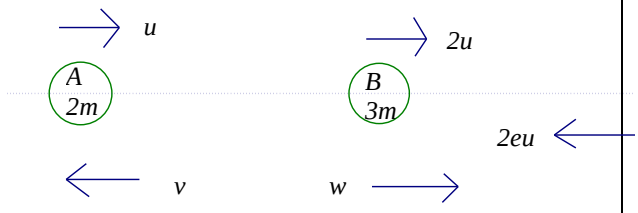
Q	Scheme	Marks	Notes
1a			
	Equation of motion:	M1	All terms required. Dimensionally correct. Condone sign errors. Condone sin/cos confusion
	$F - R - 800g\sin\theta = 800\times -0.75$	A1	Unsimplified equation with at most one error
		A1	Correct nsimplified equation
	Use of $P = Fv$: $F = \frac{18000}{15}$ $\left(=1200\right)$	B1	
	$R = 680$	A1	
		[5]	
		(5)	

Q	Scheme	Marks	Notes
2	Use of $\mathbf{I}=m\mathbf{v}-m\mathbf{u}$: $\mathbf{I}=4w(\mathbf{i}+\mathbf{j})-4\times3.5\mathbf{i}$	M1	Correct use of formula but condone subtraction in wrong order. Ignore 26 if seen
	$=(4w-14)\mathbf{i}+4w\mathbf{j}$	A1	**I** in terms of *w*. Any equivalent form Ignore 26 if seen. Accept + / -
	Magnitude of vector: $26^2=(4w-14)^2+(4w)^2$ $(32w^2-112w-480=0)$	M1	Correct use of Pythagoras to find magnitude Must square both sides.
	$(2w+5)(w-6)=0$	M1	Solve a 3 term quadratic in *w*
	$w=6$	A1	Positive root only
			Can score fill marks from $\mathbf{I}=m\mathbf{u}-m\mathbf{v}$
		[5]	
2alt	Impulse momentum triangle:  	M1	
	Angle and lengths/vectors	A1	
	$26^2=14^2+16w^2\times2-2\times14\times4w\sqrt{2}\times\frac{1}{\sqrt{2}}$ $(32w^2-112w-480=0)$	M1	Use of cosine rule:
	$(2w+5)(w-6)=0$	M1	Solve a 3 term quadratic in *w*
	$w=6$	A1	Positive root only:
		[5]	
		(5)	

Q	Scheme	Marks	Notes
3a	Differentiate to find *v*:	M1	Convincing attempt to differentiate
	$v = 4t^2 - 6t - 4$	A1	
	$4t^2 - 6t - 4 = 2\left(2t^2 - 3t - 2\right) = 2\left(2t + 1\right)\left(t - 2\right)$	DM1	Solve for $v = 0$ Dependent on the previous M1
	$\Rightarrow t = 2$	A1	Ignore $-\frac{1}{2}$ if seen
		[4]	
3b	Differentiate to find *a*: $a = 8t - 6$	M1	
	Substitute $t = 3$: $a = 8 \times 3 - 6$	DM1	Dependent on the previous M1
	$= 18$ (m s^{-2})	A1	
		[3]	
3c	Correct strategy for distance:	M1	
	$\left\lvert\left[\frac{4}{3}t^3 - 3t^2 - 4t\right]_0^2\right\rvert + \left[\frac{4}{3}t^3 - 3t^2 - 4t\right]_2^3$	A1ft	Follow their answer to (a) provided $0 \le t \le 3$
	$= \left\lvert -9\frac{1}{3} - 0\right\rvert + \left[-3 + 9\frac{1}{3}\right] = 15\frac{2}{3}$	A1	$\frac{47}{3}$ (15.7 or better) (m)
			M1A1ft is available for $\lvert$*their* first interval$\rvert + \lvert$*their* second interval$\rvert$
		[3]	
		(10)	

Q	Scheme	Marks	Notes
4a	Moments about A:	M1	Need all terms. Dimensionally correct. Condone sign errors and sin/cos confusion
	$50\times 2\cos\theta+10\times 3\cos\theta=4T$	A1	Correct unsimplified equation in T or their T
	$\left(130\cos\theta=4T\right)\quad T=30$	A1	
		[3]	
4b	Resolve $\updownarrow$:	M1	Condone sign errors and sin/cos confusion
	$T\cos\theta+R=50+10\qquad\left(R=\dfrac{420}{13}\right)$	A1	Correct unsimplified equation in T or their T
	Resolve $\leftrightarrow$:	M1	Condone sign errors and sin/cos confusion
	$T\sin\theta=F\left(=\dfrac{150}{13}\right)$	A1	Correct unsimplified equation
	Use of $F=\mu R$ to solve for μ	DM1	Dependent on both preceding M marks
	$\mu=\dfrac{150}{420}=\dfrac{5}{14}\quad\left(=0.36\right)$	A1	0.36 or better
	One of the two equations could be replaced by a second moments equation e.g. M(B): $4R\cos\theta=4\mu R\sin\theta+100\cos\theta+10\cos\theta$		For marking: 1st equation M1A1 2nd equation M1A1 Use of $F=\mu R$ M1 Answer A1
	Parallel: $R\sin\theta+\mu R\cos\theta=60\sin\theta$ Perpendicular: $R\cos\theta+T=60\cos\theta+\mu R\sin\theta$		
		[6]	
		(9)	

5a	KE gain $\frac{1}{2}(m_1+m_2)v^2$	M1	
	$=\frac{1}{2}\times 10\times 9=45$ (J)	A1	
		[2]	
5b	GPE lost $6g\times 2\sin\alpha$	M1	Condone sin/cos confusion
	$=\frac{24g}{\sqrt{5}}$ (=100 (J) (110 J))	A1	105.18.....
	Work done against friction	M1	Correct use of work-energy. All terms and no extras. Dimensionally correct. Condone sign errors
	$=2F=\frac{24g}{\sqrt{5}}-45(=60.18)$ (J)	A1ft	Or equivalent. Follow their 45 and $\frac{24g}{\sqrt{5}}$
	Use of $F=\mu R=\mu\times 4g$ to find μ	DM1	Dependent on F found using work-energy equation
	$\mu=0.77$ (0.768)	A1	2sf or 3 sf
		[6]	
		(8)	

6			
	Speed of B after impact with wall $=e\times 2u$	B1	
	CLM: $2mu-3m\times"2eu"=-2mv+3mw$	M1	Need all terms and dimensionally correct.
	$(2u-6eu=-2v+3w)$	A1ft	Correct unsimplied equation. Follow their $2eu$
	Impact law:	M1	Used correctly. Condone sign errors
	$v+w=\frac{1}{3}(u+"2eu")$	A1ft	Correct unsimplied equation. Follow their $2eu$
	Solve for multiple of v or w in terms of e and u: $v=\frac{1}{3}(u+2eu)-w$ and $3w=2u-6eu+2v$ $\Rightarrow 3w=2u-6ue+2\left(\frac{1}{3}(u+2eu)-w\right)$, $5w=\frac{8}{3}u-\frac{14}{3}ue$	DM1	Dependent on the first 2 M marks and answer involving e and u
	Solve for second speed: $v=\frac{1}{3}(u+2eu)-\frac{1}{15}(8u-14ue)\left(=-\frac{3u}{15}+\frac{24ue}{15}\right)$	DM1	Dependent on the first 2 M marks and answer involving e and u
	Inequality consistent with their directions: $5w>0$	M1	To obtain an inequality in e
	$\Rightarrow e<\frac{8}{14}\quad\left(e<\frac{4}{7}\right)$	A1	A1 for either inequality correct
	Second inequality consistent with their directions: $v>0$	M1	To obtain an inequality in e
	Combined conclusion: $\frac{1}{8}<e<\frac{4}{7}$	A1	Correct only
		[11]	
		(11)	

7a	Velocity at $A = (4\mathbf{i} - 8\mathbf{j})$ (m s^{-1})	B1	(Allow for $\lambda = 4$)
	Vertical component: $-8 = 7 - 9.8T$	M1	Complete method using *suvat* to find *T*. Condone sign errors
	$T = 1.53 \quad (1.5)$	A1	2 sf or 3 sf
		[3]	
7b	Horizontal distance: $4\times$ their $T\,(= 6.122....)$	B1ft	
	Vertical distance:	M1	Complete method using *suvat*
	$7\times$ their $T - 4.9\times(\text{their } T)^2 \left(= -0.765.... = \frac{75}{98}\right)$	A1ft	Unsimplified equation in their *T*
	$OA = \sqrt{(6.122..)^2 + (-0.765..)^2}$	M1	Use of Pythagoras' Theorem
	6.17 (m) $\quad (6.2)$	A1	2 sf or 3 sf
		[5]	
7c	Perpendicular velocity : $\mu(7\mathbf{i} - 4\mathbf{j})$	B1	
	Horizontal component $4\mathbf{i}$	B1	
	$\Rightarrow 7\mu = 4 \qquad \Rightarrow \mu = \frac{4}{7}$	M1	
	Velocity $= \left(4\mathbf{i} - \frac{16}{7}\mathbf{j}\right)$ (m s^{-1})	A1	$(4\mathbf{i} - 2.3\mathbf{j}$ or better$)$ $(4\mathbf{i} - 2.29\mathbf{j})$ Accept answer given as a magnitude and a direction.
		[4]	
7c alt	Vertical Component: 7-9.8t	B1	
	Velocity at μ : $\frac{7}{4} \times \frac{7 - 9.8t}{4} = -1$	B1	
	Solve for $t \Rightarrow$ $49 - 7gt = -16$ $65 = 7gt, \quad t = \frac{65}{7g}$	M1	
	$\Rightarrow \mathrm{v} = 4\mathbf{i} + \left(7 - \frac{65}{7}\right)\mathbf{j} = \left(4\mathbf{i} - \frac{16}{7}\mathbf{j}\right)\mathrm{ms}^{-1}$	A1	
		[4]	
		(12)	
8a	*OAB* | *OCD* | *OEF* | *L*	B1	

	<table><tr><td>Mass ratio</td><td>25</td><td>16</td><td>9</td><td>50</td></tr><tr><td>Distance from *AD*</td><td>$\frac{5}{3}a$</td><td>$\frac{4}{3}a$</td><td>$-\frac{3}{3}a$</td><td>$\bar{y}$</td></tr></table>	B1	Allow + / -
	Moments about *AD*:	M1	Or a parallel axis. Need all terms. Dimensionally correct. Condone sign errors
	$25\times\frac{5}{3}a+16\times\frac{4}{3}a-9\times\frac{3}{3}a=50\bar{y}$	A1	Correct unsimplified equation for their axis
	$\bar{y}=\frac{162}{150}a=\frac{27}{25}a$	A1	Obtain **Given Answer** from correct working
		[5]	
8b	<table><tr><td></td><td>*OAB*</td><td>*OCD*</td><td>*OEF*</td><td>*L*</td></tr><tr><td>Mass ratio</td><td>25</td><td>16</td><td>9</td><td>50</td></tr><tr><td>Distance from *BF*</td><td>$\frac{5}{3}a$</td><td>$-\frac{4}{3}a$</td><td>$-\frac{3}{3}a$</td><td>$\bar{x}$</td></tr></table>	B1	Allow + / -
	Moments about *BF*:	M1	Or a parallel axis. Need all terms. Dimensionally correct. Condone sign errors
	$25\times\frac{5}{3}a-16\times\frac{4}{3}a-9\times\frac{3}{3}a=50\bar{x}$	A1	Correct unsimplified equation for their axis
	$\bar{x}=\frac{34}{150}a \quad \left(\frac{17}{75}a\right)$	A1	$\frac{317}{75}a$ from *D*
	$\tan\theta=\frac{\bar{y}}{5a-\bar{x}}$	M1	Use of trig to find a relevant angle
	$\tan\theta=\frac{\frac{27}{25}a}{5a-\bar{x}} \quad \left(=\frac{162}{750-34}=0.2259....\right)$	A1ft	Correct unsimplified expression for the required angle. Follow their $\bar{x}$
	, $\theta=12.7° \ (13°)$	A1	(0.223 radians)
		[7]	
8c	Moments about *A*:	M1	Dimensionally correct equation in *k*
	$50M\times\frac{27}{25}a=kM\times3a$	A1	Correct unsimplified equation in *k*
	$k=18$	A1	
		[3]	
8c alt	Centre of mass lies on *AD*:	M1	Correct strategy to find *k*
	$\mu\mathbf{i}=50M\left(\frac{17}{25}a\mathbf{i}+\frac{27}{25}a\mathbf{j}\right)+kM\left(-3a\mathbf{j}\right)$	A1	Correct unsimplified equation in *k*
	$\Rightarrow 50M\times\frac{27}{25}=3kM \ , \quad k=18$	A1	
		[3]	
		(15)	

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