Mark Scheme (Results)

October 2021

Pearson Edexcel International A Level
In Mechanics M3 (WME03) Paper 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(a)	$\frac{2\pi}{\omega} = 4$	M1
	$\omega = \frac{\pi}{2}$	A1
	$2 = a\frac{\pi}{2}\cos\left(\frac{\pi}{2}\times 0.5\right) \Rightarrow 2 = a\frac{\pi}{2}\times\frac{1}{\sqrt{2}}$	M1
	$a = \frac{4\sqrt{2}}{\pi}\text{m}$ *	A1* (4)
1(b)	$v_{MAX} = \frac{4\sqrt{2}}{\pi}\times \text{their}\,\omega$	M1
	$2\sqrt{2}$ (m s^{-1})	A1 (2)
		(6)
	Notes for question 1	
1(a)	M1 Need to see this equation, as it's a 'show that'. Allow with 4 or *T* or in a rearranged form.	
	A1 seen	
	M1 Complete method to obtain an equation in *a* only Use of $x = a\sin\omega t$ to find *x* followed by $v^2 = \omega^2\left(a^2 - x^2\right)$ may be seen. (Use of $v = \pm a\omega\sin\omega t$ scores M0 (this implies *t* = 0 at an end-point.)	
	A1* Correct answer correctly obtained	
1(b)	M1 Use of $a\omega$ with the given value of *a*	
	A1 Allow 2.8 or better. Ignore units but must be positive.	

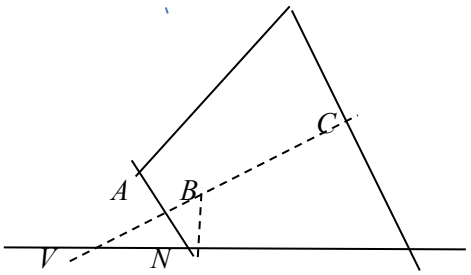
Question Number	Scheme	Marks
2(a)	$\frac{1}{\sqrt{(2x+1)}}=\frac{1}{3}\Rightarrow x=4$	M1A1
	$a=v\frac{\mathrm{d}v}{\mathrm{d}x}=\frac{1}{\sqrt{(2x+1)}}\times-\frac{1}{2}\times2(2x+1)^{-\frac{3}{2}}\quad\left(=-\left(2x+1\right)^{-2}\right)$	M1A1
	$a=(-)\frac{1}{81}$	A1
	$\frac{2}{81}$ (N), 0.025or better	A1 (6)
2(b)	$t=\int\sqrt{(2x+1)}\ \mathrm{d}x$	M1
	$t=\frac{2}{3}\times\frac{1}{2}(2x+1)^{\frac{3}{2}}+(C)$	A1
	Use of $t = 0$, $x = 0$ to obtain a value for C $(=-\frac{1}{3})$	M1
	Substitute $x = 7.5$	dM1
	$t = 21$	A1 (5)
		(11)
	Notes for question 2	
2(a)	M1 for putting $v=\frac{1}{3}$ and solving for $x$oe e.g. $(2x + 1) = 9$	
	A1 for $x = 4$ oe	
	M1 for use of $v\frac{\mathrm{d}v}{\mathrm{d}x}$ with clear attempt at differentiation. (Power $-\frac{3}{2}$ needed	
	A1 for a correct unsimplified expression for a in terms of x only	
	A1 for a correct value for a (ignore sign)	
	A1 cao (must be positive)	
2(b)	M1 for use of $\frac{\mathrm{d}x}{\mathrm{d}t}=\frac{1}{\sqrt{(2x+1)}}$, separate variables and attempt to integrate. $k\left(2x+1\right)^{\frac{3}{2}}$ should be seen	
	A1 for correct unsimplified integration, C not needed.	
	If definite integration used, ignore limits for these 2 marks	
	M1 for use of initial conditions to find a value for C	
	dM1 dependent on first M1, for substituting in $x = 7.5$ and evaluating	
	For definite integration award M1 for substitution of the lower limits and DM1 for substitutio of the upper limits.	
	A1 cao	

Question Number	Scheme	Marks
3(a)	$mg = \frac{kmg}{l}\frac{2l}{5}$	M1
	$k = \frac{5}{2}$ *	A1* (2)
3(b)	$mg - T = m\ddot{x}$	M1
	$mg - \frac{5mg}{2l}\left(x + \frac{2l}{5}\right) = m\ddot{x}$	DM1A1
	$-\frac{5g}{2l}x = \ddot{x}$, hence SHM.*	A1* (4)
3(c)	$\omega = \sqrt{\frac{5g}{2l}}$; $a = \frac{1}{4}l$	B1 **ft**; B1
	$v = a\omega = \frac{1}{4}l \times \sqrt{\frac{5g}{2l}}$	M1
	$\frac{1}{4}\sqrt{\frac{5gl}{2}}$ oe	A1 (4)
3(d)	$\frac{1}{4} \times \frac{2\pi}{\omega}$	M1
	$\frac{\pi}{2}\sqrt{\frac{2l}{5g}}$ oe	A1 **ft** (2)
		(12)
	Notes for question 3	
3(a)	M1 for $mg = T$ and use of Hooke's Law	
	A1* Given answer correctly obtained	
3(b)	M1 for equation of motion, dim correct with all necessary terms, allow a for acceleration and condone sign errors. Accept T or attempt at T, which may not have a variable extension.	
	DM1 for equation of motion, dim correct with correct terms, and use of Hooke's Law with a variable extension measured from E and now need $\ddot{x}$, condone sign errors. Depends on the first M mark; both M marks can be awarded together.	
	A1 for a correct unsimplified equation	
	A1* for a correct equation and conclusion	
3(c)	B1 ft for a dimensionally correct ω or ω^2, seen explicitly or used. B1 for $a = \frac{1}{4}l$	
	M1 for use of $v = a\omega$ or $v^2 = \omega^2\left(a^2 - x^2\right)$ with $x = 0$ later	
	A1 cao	
	Use of energy: B1 gain of GPE B1 either EPE M1 energy equation with change in GPE, change in EPE and KE. A1 cao	
3(d)	M1 for use of $\frac{1}{4} \times \frac{2\pi}{\omega}$	
	A1 cao	

Question Number	Scheme	Marks
4(a)	WD against air resistance $= kmga$; PE Gain $= \frac{1}{2}mga$; KE Gain $= \frac{1}{2}\times\frac{1}{2}m\times 3ag$	B2,1,0
	Initial EPE $= \frac{2mg}{4a}(2a)^2$; Final EPE $= \frac{2mg}{4a}a^2$	B1; B1
	$kmga = \frac{2mg}{4a}\left((2a)^2 - a^2\right) - \frac{1}{2}mga - \frac{1}{2}\times\frac{1}{2}m\times 3ag$	M1A1
	$k = \frac{1}{4}$ *	A1* (7)
4(b)	$\frac{1}{2}mg - \frac{1}{4}mg - T = 0$	M1
	$\frac{1}{2}mg - \frac{1}{4}mg - \frac{2mg}{2a}x = 0$	A1
	$x = \frac{1}{4}a$	A1
	$OB = \frac{9a}{4}$	A1 ft (4)
		(11)
	Notes for question 4	
4(a)	B2 for all 3 unsimplified terms. B1 B0 for 2 out of 3 corrrect	
	B1 for the initial EPE	
	B1 for the final EPE	
	M1 for the work-energy equation with all necessary terms, condone sign errors.	
	A1 for a correct equation.	
	A1* for the given answer correctly obtained. At least one step of working to be seen.	
4(b)	M1 for a vertical resolution with the correct terms (*T* does not need to be substituted) Must have acceleration = 0 for this mark	
	A1 for a correct equation with *T* replaced.	
	A1 cao	
	A1ft $2a$ + their x	
	Use of uniform aceleration equations scores 0/4	
	Alternative, using work-energy	
	M1 for an equation with GPE, EPE, KE and WD terms – all but KE using a variable distance (*OB* or the extension).	
	A1 correct equation	
	DM1 (A1 on e-pen) Obtain an expression for v^2 in terms of their unknown distance **and** find their distance when this is maximum by calculus or completing the square	
	A1 cao	

Question Number	Scheme	Marks
5(a)	$\cos\alpha = \frac{3}{5}$, where angle $ARP = \alpha$ oe	B1
	For R, $(\updownarrow)$ $T_2\cos\alpha = mg$ oe	M1
	$T_2 = \frac{5mg}{3}$ *	A1* (3)
5(b)	For P, $(\updownarrow)$ $T_1\cos\alpha - \frac{5mg}{3}\cos\alpha = mg$ or $T_1\cos\alpha = 2mg$	M1A1
	Equation of motion: $T_1\sin\alpha + \frac{5mg}{3}\sin\alpha = m(l\sin\alpha)\omega^2$ oe	M1A2,1,0
	$\omega = \sqrt{\frac{5g}{l}}$	A1
	Time = $\frac{2\pi}{\omega}$	M1
	$= 2\pi\sqrt{\frac{l}{5g}}$ oe	A1 (8)
		(11)
	Notes for question 5	
5(a)	B1 for sine or cosine of a relevant angle. May be seen in (b).	
	M1 for resolving vertically for the ring R, with usual rules	
	A1* for given answer correctly obtained.	
5(b)	M1 for resolving vertically for P, with usual rules. This may have been seen in (a) and **used** in (b)	
	A1 for a correct equation (trig does not need substituting)	
	M1 for horizontal equation of motion for P, with usual rules. The acceleration can be in either form and accept "r" for $l\sin\alpha$	
	A2 for a correct equation, give A1A0 for an equation with at most one error (allow the sines to have been cancelled)	
	A1 cao	
	M1 for a correct method	
	A1 cao	

Question Number	Scheme	Marks
6(a)	$\frac{1}{2}mv^2 - \frac{1}{2}mu^2 = mga(\cos\alpha - \cos\theta)$	M1A2,1,0
	$v^2 = u^2 + \frac{2ag}{5}(4 - 5\cos\theta)$ *	A1* (4)
6(b)	$T + mg\cos\theta = \frac{mv^2}{a}$ (T may be omitted here)	M1A2,1,0
	Use of $T = 0$ and substitute for v^2 and u^2	DM1
	$mg\cos\beta = \frac{m}{a}\left(\frac{6ag}{5} + \frac{2ag}{5}(4 - 5\cos\beta)\right)$	A1
	$\cos\beta = \frac{14}{15}$ (0.93 or better)	A1 (6)
		(10)
	Notes for question 6	
6(a)	M1 for an energy equation with the 2 KE terms and 2 PE terms. $\cos\alpha$ must be seen.	
	A2 for a correct equation, A1A0 for an equation with at most one error	
	A1* for the given answer correctly obtained.	
6(b)	M1 for an equation of motion towards O with all necessary terms, condone sign errors and sin/cos confusion mg must be resolved	
	A2 for a correct equation (allow $-T$), A1A0 for an equation with at most one error	
	DM1 for use of $T = 0$ and substitute for v^2 and u^2 to obtain an equation in $\cos\beta$ Depends on the first M mark of (b)	
	A1 Correct unsimplified equation following substitution	
	A1 cao	

Question Number	Scheme	Marks
7(a)	$\bar{x} = \dfrac{\int_0^h x\left(\dfrac{rx}{h}\right)^2 \mathrm{d}x}{\int_0^h \left(\dfrac{rx}{h}\right)^2 \mathrm{d}x}$ (Allow volume of cone formula quoted with π in the numerator)	M1DM1
	$= \dfrac{\left[\dfrac{x^4}{4}\right]_0^h}{\left[\dfrac{x^3}{3}\right]_0^h}$ oe	A1
	$= \dfrac{3h}{4}$ *	A1* (4)
7(b)	F C C' Distance $\bar{y}$ $\dfrac{1}{4}h$ $\dfrac{2h}{3}+\left(\dfrac{1}{4}\times\dfrac{h}{3}\right)$ $\left(=\dfrac{3h}{4}\right)$ Mass ratio 26 27 1 oe	B1 B1
	$26\bar{y} = \dfrac{1}{4}h\times 27 - \left[\dfrac{2h}{3}+\left(\dfrac{1}{4}\times\dfrac{h}{3}\right)\right]\times 1$	M1A1ft
	$\bar{y} = \dfrac{3}{13}h$ *	A1* (5)
7(c)		
	For equilibrium, $\bar{y} = \dfrac{3}{13}h \leq CB$ oe	M1
	$\dfrac{AB}{AN} = \dfrac{AN}{AV} \Rightarrow AB = \dfrac{1}{3}r\times\dfrac{r}{h} = \dfrac{r^2}{3h}$ oe	M1A1
	So, for equilibrium, $\dfrac{3}{13}h \leq \dfrac{2}{3}h - \dfrac{r^2}{3h}$	M1
	$13r^2 \leq 17h^2$ *	A1* (5)
		(14)

Question Number	Scheme	Marks
	Notes for question 7	
7(a)	M1 for use of $\int_0^h xy^2 \mathrm{d}x$ (Attempt at integration required)	
	DM1 for use of $\bar{x} = \dfrac{\int_0^h x\left(\dfrac{rx}{h}\right)^2 \mathrm{d}x}{\int_0^h \left(\dfrac{rx}{h}\right)^2 \mathrm{d}x}$ Depends on M mark above	
	A1 for $= \dfrac{\left[\dfrac{x^4}{4}\right]_0^h}{\left[\dfrac{x^3}{3}\right]_0^h}$	
	A1* for given answer correctly obtained. Upper limit(s) must be substituted.	
7(b)	B1 for distances from larger plane face or any parallel axis	
	B1 for mass (volume) ratios	
	M1 for moments about larger plane face or any parallel axis	
	A1ft for a correct equation, follow through their distances and masses	
	A1* for given answer correctly obtained. At least one step in the working from the equation must be seen.	
7(c)	M1 for overall method using a suitable inequality – may be comparing lengths or angles. If the limiting case is used this mark (and the final A mark) can only be awarded if a reason for the direction of the inequality is seen (eg $\bar{y}$ „ CB)	
	M1 for finding a length appropriate for their method	
	A1 for a correct relevant distance in terms of r and h	
	M1 for producing an inequality in r and h, must be right way round	
	A1* for correctly showing given inequality. At least one step in the working from their previous inequality must be seen.	

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