Pearson Edexcel

Mark Scheme (Unused)

January 2022

Pearson Edexcel International Advanced 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.
- 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

Question Number	Scheme	Marks
1(a)	$T_{AP} = 6mg$	M1
	$\frac{6mgx}{8a} = 6mg$	M1
	$AP = 16a$	A1
		(3)
1(b)	$2mg = \frac{6mgy}{3a}$	M1
	$y = a$	A1
	$PQ = 4a$	A1 (3)
		(6)
	Notes for question 1	
1(a)	M1 for resolving vertically for the system	
	M1 Use of Hooke's Law to set up an equation using their tension M0 if $11a$ is used for natural length	
	A1 cao	
1(b)	M1 M0 if $11a$ is used for natural length	
	A1 cao	
	A1 cao	

Question Number	Scheme	Marks
2.	$T\cos\theta(+R) = mg$	M1A1
	$T\sin\theta = ma\sin\theta\dfrac{2g}{a}$ $\quad (T = 2mg)$	M1A1
	$\cos\theta < \dfrac{1}{2}$ or $\cos\theta \le \dfrac{1}{2}$ or $\cos\theta = \dfrac{1}{2}$	M1
	$\theta > 60$ or $\theta \ge 60$	A1
	$90 > \theta > 60$ or $90 > \theta \ge 60$	A1
		(7)
	Notes for question 2	
	M1 for resolving vertically, correct no. of terms, T resolved	
	A1 for a correct equation	
	M1 for equation of motion horizontally	
	A1 for a correct unsimplified equation	
	M1 for producing an appropriate inequality in $\cos\theta$ Allow an equation	
	A1 Must come from an inequality.	
	A1 cao	
3(a)	$a = v\dfrac{\mathrm{d}v}{\mathrm{d}x} = -\dfrac{2}{(2x+1)^3}$ separate and integrate	M1
	$\dfrac{1}{2}v^2 = \dfrac{1}{2(2x+1)^2} + (C)$	A1
	$x = 0, v = 1 \Rightarrow C = 0$	M1
	$v = \dfrac{1}{(2x+1)}$	A1
		(4)
3(b)	$\dfrac{\mathrm{d}x}{\mathrm{d}t} = \dfrac{1}{(2x+1)}$ separate and integrate	M1
	$x^2 + x + (D) = t$	A1
	Complete the square: $(x+\frac{1}{2})^2 - \frac{1}{4} = t$ or use quadratic formula: $x = \dfrac{-1 \pm \sqrt{1+4t}}{2}$	M1
	$x = \dfrac{1}{2}(\sqrt{(4t+1)} - 1)$ *	A1* (4)
		(8)
	Notes for question 3	
3(a)	M1 allow omission of - sign, powers increasing by 1	
	A1 correct equation, but allow omission of C	
	M1 use of initial conditions to find C	
	A1 cso	
3(b)	M1 powers increasing by 1	
	A1 correct equation, but allow omission of D	

Question Number	Scheme	Marks
	M1 complete the square	
	A1* given answer correctly obtained, with at least one line of working and justification of positive root e.g. $x > 0$	
4(a)	$\overline{x} = \dfrac{\pi\int_0^r x\left(r^2 - x^2\right)\mathrm{d}x}{\frac{2\pi r^3}{3}}$	M1A1
	$= \dfrac{\left[r^2\frac{x^2}{2} - \frac{x^4}{4}\right]_0^r}{\frac{2r^3}{3}}$	A1
	$= \frac{3r}{8}$*	A1*
		(4)
4(b)	Mass ratios: $\frac{2\pi r^3}{3}$ $\quad \pi r^2 h$ $\quad \left(\frac{2\pi r^3}{3} + \pi r^2 h\right)$ Distances: $\frac{5r}{8}$ $\quad \left(r + \frac{1}{2}h\right)$ $\quad \overline{y}$	B1 B1
	$\left(\frac{2\pi r^3}{3} \times \frac{5r}{8}\right) + \pi r^2 h\left(r + \frac{1}{2}h\right) = \left(\frac{2\pi r^3}{3} + \pi r^2 h\right)\overline{y}$	M1A1
	$\overline{y} = \dfrac{5r^2 + 12rh + 6h^2}{8r + 12h}$ *	A1*
		(5)
4(c)	$r = \dfrac{5r^2 + 12rh + 6h^2}{8r + 12h}$	M1
	$r = \sqrt{2}h$	A1
		(2)
		(11)
	Notes for question 4	

Question Number	Scheme	Marks
4(a)	M1 for use of $\bar{x} = \dfrac{\pi\int_0^r xy^2\,\mathrm{d}x}{\frac{2\pi r^3}{3}}$	
	A1 for $\bar{x} = \dfrac{\pi\int_0^r x\left(r^2 - x^2\right)\mathrm{d}x}{\frac{2\pi r^3}{3}}$	
	M1 for integrating with powers increasing by 1	
	A1* for given answer correctly obtained	
4(b)	B1 correct mass ratios	
	B1 correct distances (for their parallel axis)	
	M1 for use of a moments equation with correct terms (Allow about a parallel axis)	
	A1 for correct unsimplified equation (for their parallel axis)	
	A1* for given answer correctly obtained	
4(c)	M1 for equating given answer to r oe	
	A1 cao	

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Question Number	Scheme	Marks
5(a)	$\frac{1}{2}mu^2 - \frac{1}{2}mv^2 = mga(1+\cos\theta)$	M1A2,1,0
	$mg\cos\theta = \frac{mv^2}{a}$	M1A1
	Eliminate θ	M1
	$3v^2 = u^2 - 2ag$ *	A1*
		(7)
5(b)	Vertical motion: $-\frac{a\sqrt{3}}{2} = (v\sin 30^o)T - \frac{1}{2}gT^2$	M1A1
	Solve for T: $T = \frac{v \pm \sqrt{v^2 + 4ag\sqrt{3}}}{2g}$	M1
	Use $v^2 = ag\frac{\sqrt{3}}{2}$ and $T > 0$ to show the given answer: $T = \frac{2v}{g}$	A1*
		(4)
5(c)	Horizontal motion: $x = v\cos 30^o \times \frac{2v}{g}$	M1
	$= \frac{3a}{2}$ and hence taut (= a + $a$sin30°)*	A1*
		(2)
		(13)
	Notes for question 5	
5(a)	M1 for an energy equation with the correct terms	
	A2 for a correct equation, A1 for an equation with at most one error	
	M1 for an equation of motion towards O with correct terms, condone sign errors and sin/cos confusion (R may appear)	
	A1 for a correct equation (R = 0 must be used at some point)	
	M1 for eliminating θ	
	A1* for given answer correctly obtained	
5(b)	M1 for equation for vertical motion ,with correct terms, condone sign errors and sin/cos confusion	
	A1 for a correct equation	
	M1 for solving for T	
	A1* for correctly obtaining the given answer	
5(c)	M1 for equation for horizontal motion ,with correct terms, condone sign errors and sin/cos confusion	
	A1* for given answer correctly justified	

Question Number	Scheme	Marks
6(a)	$mg = \frac{\lambda \times 4l}{2l} \Rightarrow \lambda = \frac{1}{2}mg$	M1 A1
	$mg - \frac{\frac{1}{2}mg(x+4l)}{2l} = m\ddot{x}$ (or x replaced by $-x$ on both sides)	M1 A2,1,0
	$-\frac{g}{4l}x = \ddot{x}$, hence SHM (with $\omega = \sqrt{\frac{g}{4l}}$)	A1
	$T = \frac{2\pi}{\omega}$	M1
	$2\pi\sqrt{\frac{4l}{g}} = 4\pi\sqrt{\frac{l}{g}}$ *	A1*
		(8)
6(b)	Their $\omega \times 2l$	M1
	$\sqrt{gl}$	A1
	$\frac{1}{2}mgl$	A1
		(3)
6(c)	$-l = 2l\cos\omega t$	M1A1
	$t = \frac{2\pi}{3\omega}$	M1
	$\frac{1}{3}T$	A1
		(4)
		(15)
	Notes for question 6	
6(a)	M1 Resolving vertically and using Hooke's Law	
	A1 cao	
	M1 equation of motion in a general position with correct no. of terms, allow use of accln instead of derivative	
	A2 for a correct equation, A1 for an equation with at most one error	
	A1 for correct equation in correct form	
	M1 Use of correct formula	
	A1* Given answer correctly obtained	
6(b)	M1 for use of correct formula	
	A1 for correct speed	
	A1 cao	
6(c)	M1 for complete method to find *t*	
	A1 for correct equation(s) (ω does not need to be substituted for this mark)	
	M1 for solving for *t*	
	A1 cso	

Question Number	Scheme	Marks
7(a)	EPE Gain = $\dfrac{2mgx^2}{2a}$	B1
	PE loss = $mgx\sin\alpha$	B1
	WD against friction = $\mu mg\cos\alpha \times x$	B1
	$\mu mg\cos\alpha \times x = mgx\sin\alpha - \dfrac{2mgx^2}{2a}$	M1
	$x = AB = a(\sin\alpha - \mu\cos\alpha)$ *	A1*
		(5)
7(b)	$\mu mg\cos\alpha \times y = mgy\sin\alpha - \dfrac{1}{2}mv^2 - \dfrac{2mgy^2}{2a}$	M1A2,1,0
	At max speed, $\mu mg\cos\alpha = mg\sin\alpha - \dfrac{2mgy}{a}$	M1
	$y = \dfrac{1}{10}a$	A1
	Use their y value to find the max speed	M1
	$v = \sqrt{\dfrac{ag}{50}}$ oe	A1
		(7)
7(b)	$\mu mg\cos\alpha \times y = mgy\sin\alpha - \dfrac{1}{2}mv^2 - \dfrac{2mgy^2}{2a}$	M1A2,1,0
7(c)	At B, nett force down plane = $\dfrac{3}{5}mg - \dfrac{2mgx}{a} = \dfrac{1}{5}mg$	M1
	Max friction available = $\dfrac{1}{2}\times mg\times\dfrac{4}{5} = \dfrac{2}{5}mg$	B1
	Hence, friction = $\dfrac{1}{5}mg$ up and P remains at B.	A1
		(3)
		(15)
	Notes for question 7	
7(a)	B1 correct expression	
	B1 correct expression	
	B1 correct expression	
	M1 for energy equation dim correct with correct terms, condone sign errors	
	A1* for given answer correctly obtained	
7(b)	M1 for energy equation, dim correct with correct terms, condone sign errors	
	A2 for a correct unsimplified equation, A1 for for a correct unsimplified equation with at most one error	
	M1 for finding the resultant force parallel to the plane and equating to 0 or differentiating energy equation wrt y and equating $\dfrac{\mathrm{d}v}{\mathrm{d}y}$ to 0	

Question Number	Scheme	Marks
	A1 for correct value of y	
	M1 for using their y value to find the max speed	
	A1 cao	
7(b)	M1 for energy equation, dim correct with correct terms, condone sign errors	
7(c)	M1 for finding nett force up or down plane, correct terms, condone sign errors	
	B1 for max friction	
	A1 correct conclusion and justification	