Pearson Edexcel

Mark Scheme (Results)

January 2025

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.
- 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 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:

<u>'M' marks</u>

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.

<u>'A' marks</u>

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.

<u>'B' marks</u>

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 $\sqrt{}$ 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.

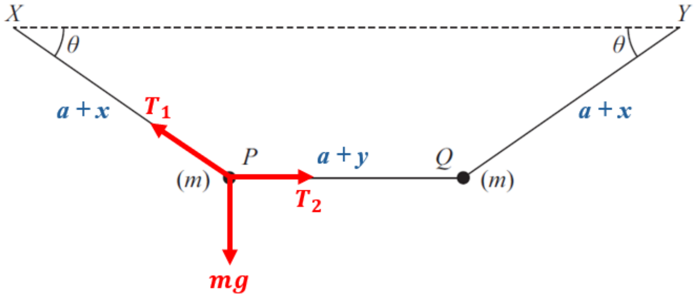
- Marks must be entered in the same order as they appear on the mark scheme.
- In all cases, if the candidate clearly labels their working under a particular part of a question i.e. (a) or (b) or (c),……then that working can only score marks for that part of the question.
- Accept column vectors in all 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

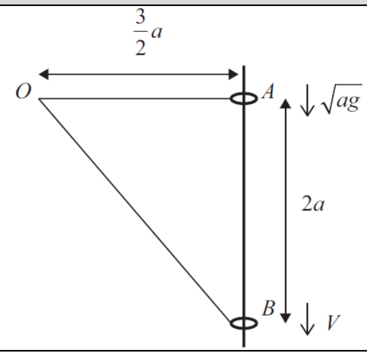
M(A)	Taking moments about A.
N2L	Newton’s Second Law (Equation of Motion)
NEL	Newton’s Experimental Law (Newton’s Law of Impact)
HL	Hooke’s Law
SHM	Simple harmonic motion
PCLM	Principle of conservation of linear momentum
RHS, LHS	Right hand side, left hand side

Question Number	Scheme	Marks
1(a)	Differentiate the second expression, $v\left(t \geqslant 4\right)$ wrt t	M1
	Correct derivative $\left(a=\right)\dfrac{1}{4}t+\dfrac{8}{t^2}$	A1
	$t = 8$, $\left(a=\right)\ \dfrac{17}{8}=2\dfrac{1}{8}$ oe	A1
		(3)
1(b)	Equate velocity expressions, substitute $t = 4$ and solve for k $\dfrac{1}{8}(4)^2=\dfrac{1}{8}(4)^2-\dfrac{8}{(4)}+k \quad \Rightarrow \quad k=...$	M1
	$k = 2$	A1
	Integrate $v\left(0 \leqslant t<4\right)$ wrt t $\displaystyle\int\frac{1}{8}t^2\mathrm{d}t=\frac{1}{24}t^3 \quad (+\,C)$	M1
	Integrate $v\left(t \geqslant 4\right)$ wrt t $\displaystyle\int\frac{1}{8}t^2-\frac{8}{t}+\text{"2"}\mathrm{d}t=\frac{1}{24}t^3-8\ln t+\text{"2"}t \quad (+\,C)$	M1
	Either • a correct **definite** integral • **and** the correct limits, 4 and 8. $\left[\dfrac{1}{24}t^3-8\ln t+\text{"2"}t\right]_4^8$ **Or** • a correct **indefinite** integral $\dfrac{1}{24}t^3-8\ln t+\text{"2"}t+C$ • **and** use $t = 4$ to equate distances to find an expression for the constant of integration $\dfrac{4^3}{24}=\dfrac{4^{\ 3}}{24}-8\ln 4+4(\text{"2"})+C$	A1 ft
	$\left(x=\right)\ \dfrac{88}{3}-8\ln 2$	A1
		(6)
		(9)
	Notes for question 1	
Note: There is a calculator warning so candidates must show their differentiation and integration.		
(a)		
M1	Differentiate the second expression wrt t, with both powers decreasing by 1. M0 if numerical answer appears without sight of the derivative.	
A1	Correct derivative, accept $\dfrac{2t}{8}+8t^{-2}$, $\dfrac{1}{4}t+\dfrac{8}{t^2}$ o.e.	
A1	Correct answer, accept 2.125, 2.13, 2.1	
(b)		

Question Number	Scheme	Marks
M1	Equate the given expressions for v, substitute $t = 4$ and solve for k. If k is found in part (a) it must be used in (b) to earn the marks.	
A1	Correct answer for k	
M1	Attempt to integrate $v\left(0 \leqslant t < 4\right)$ wrt t, with power of t increasing by 1. M0 if numerical answer appears without sight of the integral. $\left(\text{no need to evaluate to } \frac{8}{3} \text{ at this stage}\right)$	
M1	Attempt to integrate $v\left(t \geqslant 4\right)$ wrt t, with a power of t increasing by 1 and a ln$t$. Condone working with k or their numerical k. M0 if numerical answer appears without sight of the integral.	
A1ft	Integrate $v\left(t \geqslant 4\right)$ wrt t. Condone working in terms of k or ft on their numerical k. $\left(\frac{80}{3} - 8\ln 2 \text{ oe may be seen but is not necessary for this mark}\right)$ $\left(C = 8\ln 4 - 8 \text{ oe may be seen but is not necessary for this mark}\right)$	
A1	Correct answer, $\frac{88}{3} - 8\ln 2$, $\frac{88}{3} + 8\ln\frac{1}{2}$, $\frac{88}{3} + 8\ln 0.5$ Accept equivalent exact form but must have fractions combined and ln terms combined	

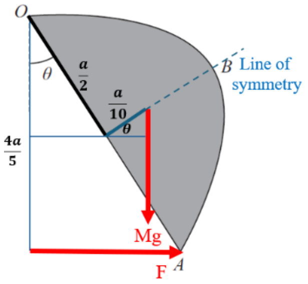
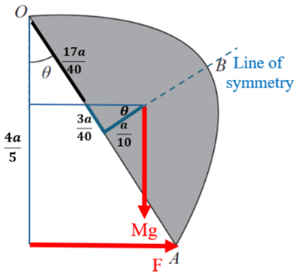
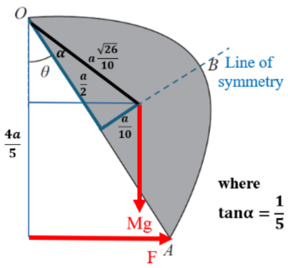
Question Number	Scheme	Marks
2		
	First relevant force equation	M1
	Correct unsimplified equation Relevant force equations: • Horiz $T_1\cos\theta = T_2$ Vert $T_1\sin\theta = mg$ or $2T_1\sin\theta = 2mg$ • // $T_1 = T_2\cos\theta + mg\sin\theta$ Perp $T_2\sin\theta = mg\cos\theta$ (accept $T_2\tan\theta = mg$) • Lami $\dfrac{T_2}{\sin(90+\theta)} = \dfrac{mg}{\sin(180-\theta)} = \dfrac{T_1}{\sin 90}$ $\dfrac{T_2}{\cos\theta} = \dfrac{mg}{\sin\theta} = \dfrac{T_1}{\sin 90}$ It may be useful to note the simplified expressions for tensions are $T_1 = \dfrac{5mg}{3}$, $T_2 = \dfrac{4mg}{3}$ but need not be seen explicitly.	A1
	Second relevant force equation	M1
	Correct unsimplified equation	A1
	Hooke's Law for either tension $T_1 = \dfrac{\frac{20mg}{7}x}{a}$ or $T_2 = \dfrac{\frac{20mg}{7}y}{a}$	B1
	Solve their relevant force equation(s) and HL to find x or y	M1
	$x = \dfrac{7a}{12}$, $y = \dfrac{7a}{15}$	A1 A1
	$(XY =)\ 2(a+x)\cos\theta + (a+y)$	DM1
	$= 4a$	A1
		(10)
	Notes for question 2	
M1	First relevant force equation. All required forces present with no extras, condone sign errors and sin/cos confusion. M0 if $T_{XP} = T_{PQ}$ or $T_{PQ} = T_{QY}$. Condone W instead of mg.	
A1	Correct unsimplified equation. Condone W instead of mg.	

Question Number	Scheme	Marks
M1	Second relevant force equation.To be relevant, it must be possible to combine with the first force equation to find both T_1 and T_2. All required forces present with no extras, condone sign errors and sin/cos confusion. Condone W instead of mg. M0 if $T_{XP} = T_{PQ}$ or $T_{PQ} = T_{QY}$.	
A1	Correct unsimplified equation. Condone W instead of mg.	
B1	Correct use of Hooke's Law. Accept with extension in terms of the lengths PX and QY. Eg $T_1 = \frac{\frac{20mg}{7}(PX - a)}{a}$ $T_2 = \frac{\frac{20mg}{7}(QY - a)}{a}$	
M1	Solve their relevant force equation and HL to find the unknown extension (x or y) or length PX or QY in terms of a. HL must be of the form $\frac{\lambda x}{ka}$ where k is a constant. If using W, it must be replaced with mg.	
A1	One correct (x or y) or (PX or QY) $PX = \frac{19a}{12}$ $QY = \frac{22a}{15}$	
A1	Both correct (x and y) or (PX and QY)	
DM1	Dependent on the first two method marks. Complete expression for XY with calculated x and y, condone sin/cos confusion.	
A1	cao	

Question Number	Scheme	Marks
3		
	Attempt to find final extension: $\sqrt{\left(\left(\frac{3a}{2}\right)^2+(2a)^2\right)}-a$	M1
	Method to find at least one expression for EPE	M1
	Two correct expressions for EPE (final and initial) $\frac{mg}{2a}\left(\frac{3a}{2}\right)^2,\ \frac{mg}{2a}\left(\frac{a}{2}\right)^2$	A1
	GPE Loss = $mg\times 2a$	B1
	Use of conservation of mechanical energy	M1
	$mg\times 2a+\frac{1}{2}mag+\frac{mg}{2a}\left(\frac{a}{2}\right)^2=\frac{1}{2}mV^2+\frac{mg}{2a}\left(\frac{3a}{2}\right)^2$ $\left(2mga+\frac{1}{2}mag+\frac{mga}{8}=\frac{1}{2}mV^2+\frac{9mga}{8}\right)$	A1
	$(V=)\ \sqrt{3ag}$	A1
		(7)
	Notes for question 3	
M1	Complete method to find the final extension (their $OB-a$). May see use of the 3,4,5 triangle or Pythagoras to find OB. May be implied by a correct final extension.	
M1	Method using EPE formula at least once. EPE must have the form $\frac{\lambda x^2}{k\,a}$ where λ is modulus of elasticity, x is their extension and k is a constant (condone $k=1$).	
A1	Two correct expressions for EPE	
B1	GPE term seen or implied	
M1	Use of the principle of conservation of mechanical energy. All required terms present and of the correct structure with no extras (2 EPE, 2KE, GPE). Condone sign errors. Note there are different rearrangements. For example, Initial = Final $mg\times 2a+\frac{1}{2}mag+\frac{mg}{2a}\left(\frac{a}{2}\right)^2=\frac{1}{2}mV^2+\frac{mg}{2a}\left(\frac{3a}{2}\right)^2$	

Question Number	Scheme	Marks
	Gain = Loss $\quad \frac{1}{2}mV^2 - \frac{1}{2}mag + \frac{mg}{2a}\left(\frac{3a}{2}\right)^2 - \frac{mg}{2a}\left(\frac{a}{2}\right)^2 = mg \times 2a$	
A1	Correct unsimplified equation	
A1	Correct answer in terms of a and g, accept $1.3\sqrt{ag}$ or better	

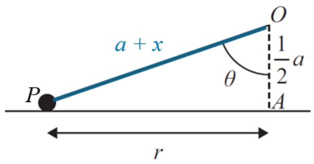
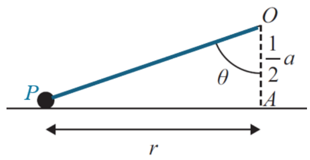
Question Number	Scheme	Marks
4(a)	Use of $\frac{1}{2}\int y^2\ \mathrm{d}x$ with $y = \frac{1}{a}(ax - x^2)$ to integrate the expression $\left(\frac{1}{2}\right)\left(\frac{1}{a}(ax - x^2)\right)^2$ oe	M1
	Correct integration $\left(\frac{1}{2}\right)\frac{1}{a^2}\left[\frac{a^2x^3}{3} - \frac{2ax^4}{4} + \frac{x^5}{5}\right]$	A1
	Use of $\int y\ \mathrm{d}x$ with $y = \frac{1}{a}(ax - x^2)$ to integrate the expression $\frac{1}{a}(ax - x^2)$ oe	M1
	Correct integration $\frac{1}{a}\left[\frac{ax^2}{2} - \frac{x^3}{3}\right]$	A1
	Correct use of centre of mass formula for $\bar{y}$ with $y = \frac{1}{a}(ax - x^2)$ $\bar{y} = \dfrac{\frac{1}{2}\int_0^a \frac{1}{a^2}(ax - x^2)^2\mathrm{d}x}{\int_0^a \frac{1}{a}(ax - x^2)\mathrm{d}x} \quad \left(= \dfrac{\frac{a^3}{60}}{\frac{a^2}{6}}\right)$	M1
	$(\bar{y} =)\ \frac{1}{10}a$	A1

Question Number	Scheme	Marks
		(6)
4(b)	$\overline{x} = \frac{1}{2}a$	B1
	Horizontal distance of G from the vertical at O Examples of valid methods  $\frac{a}{2}\sin\theta + \frac{a}{10}\cos\theta$ $\frac{17a}{40}\sin\theta + \frac{a}{8}$ $\frac{a\sqrt{26}}{10}\sin(\theta+\alpha)$	M1
	Correct horizontal distance $\frac{19a}{50}$	A1
	Moments equation about O to form an equation in F, M, θ (and g)	DM1
	$Fa\cos\theta = Mg \times d$	A1
	$F = \frac{19Mg}{40}$ oe	A1
		(6)
		(12)
	Notes for question 4	
4(a)		
M1	Attempt to integrate $\frac{1}{2}y^2$ with $y = \frac{1}{a}(ax - x^2)$. Must see at least two powers of x increasing by 1. Ignore any limits and condone missing $\frac{1}{2}$. The correct expansion to integrate is $\left(\frac{1}{2}\right)\frac{1}{a^2}(a^2x^2 - 2ax^3 + x^4)$ oe. Condone a slip when expanding the brackets before integration.	
A1	Correct integrated expression (ignore limits, condone missing $\frac{1}{2}$)	
M1	Attempt to integrate y with $y = \frac{1}{a}(ax - x^2)$. Must see both powers of x increase by 1. Ignore any limits.	
A1	Correct integrated expression (ignore limits)	

Question Number	Scheme	Marks
M1	Complete method to find $\bar{y}$. Use of the correct formula (up the right way). If ρ appears it must appear in both numerator and denominator. Limits must be correct and $\frac{1}{2}$ must be present. $$\bar{y}=\frac{\frac{1}{2}\int_0^a \frac{1}{a^2}(ax-x^2)^2\,dx}{\int_0^a \frac{1}{a}(ax-x^2)dx}$$	
A1	Correct answer, $\frac{1}{10}a$ or $0.1a$ oe	
4(b)		
B1	$\bar{x}=\frac{1}{2}a$ seen or implied. May be seen on diagram, embedded in a length eg $\frac{1}{2}a\sin\theta$ or found from first principles using $\bar{x}\int_0^a y\,dx=\int_0^a xy\,dx$	
M1	A complete method to obtain the required horizontal distance from *G* to the vertical at *O*. For example, method to find the lengths of two right-angled triangles that sum to the required distance. Condone sin/cos confusion.	
A1	Correct horizontal distance	
DM1	Dependent on first method mark. Moments about *O*, using the horizontal distance, to obtain an equation in *F*, *M* and θ (and *a*). Dimensionally correct with all required terms of the correct structure and no extras. Condone sin/cos confusion. Missing *g* is an accuracy error.	
A1	Correct unsimplified equation.	
A1	Accept $0.48Mg$ or $0.475Mg$ (must be in terms of *M* and *g*)	

Question Number	Scheme	Marks
5(a)	$\frac{1}{2}mU^2 - \frac{1}{2}mV^2 = mg\left(a + \frac{a}{4}\sin\theta\right)$	M1A1A1
	$V^2 = U^2 - \frac{ag}{2}\left(4+\sin\theta\right)$ *	A1*
		(4)
5(b)	Equation of motion towards the peg	M1
	$T + mg\sin\theta = m\frac{V^2}{\left(\frac{a}{4}\right)}$	A1
	Eliminate V^2 $$T + mg\sin\theta = \frac{4m}{a}(U^2 - \frac{ag}{2}(4+\sin\theta))$$	DM1
	$T = \frac{4mU^2}{a} - 8mg - 3mg\sin\theta$	A1
		(4)
5(c)	Substitute $U = \sqrt{\frac{19ag}{8}}$ and $T = 0$ in their equation of motion and solve for $\sin\theta$ $$\frac{4m}{a}\left(\sqrt{\frac{19ag}{8}}\right)^2 - mg(8+3\sin\theta) = 0 \quad \Rightarrow \quad \sin\theta = ...$$	M1
	$\sin\theta = \frac{1}{2} \quad \Rightarrow$ height $= \frac{1}{8}a$	A1
		(2)
		(10)
	Notes for question 5	
5(a)		
M1	Energy equation with the correct number of terms (2KE, GPE). All terms dimensionally correct and with the correct structure. Condone sign errors and sin/cos confusion. Must include m in each term.	
A1	Correct unsimplified equation with at most one error	
A1	Correct unsimplified equation	
A1*	Answer obtained from complete and correct working. There must be at least one line of working or simplification between the initial equation and the given answer. Accept $V^2 = U^2 - \frac{ag}{2}\left(\sin\theta+4\right)$, $V^2 = U^2 - \frac{1}{2}ag\left(4+\sin\theta\right)$, $V^2 = U^2 - \frac{1}{2}ag\left(\sin\theta+4\right)$	
5(b)		
M1	Equation of motion towards the peg. Must have all required terms and no extras. Condone sin/cos confusion and sign errors. Accept any form of acceleration, condone 'a' for acceleration for the method mark only.	

Question Number	Scheme	Marks
A1	Correct equation using the form $\frac{v^2}{r}$ for acceleration where $r = \frac{a}{4}$	
DM1	Dependent on the first M. Use the given answer from (a) to eliminate V^2 from their equation of motion and form an equation in T, m, g , u, a and θ. Condone a slip when transferring the expression for V^2 as long as the intention to use the expression given in (a) is clear.	
A1	A correct expression for T with $\sin\theta$ terms collected. ISW once the correct expression is seen with collected terms.	
5(c)		
M1	Substitute $U^2 = \frac{19ag}{8}$ and $T = 0$ in their equation of motion to find a value for $\sin\theta$. M0 for using $V = 0$.	
A1	Correct answer, accept $0.13a$ and $0.125a$	

<table>
<tr><th>Question Number</th><th colspan="2">Scheme</th><th>Marks</th></tr>
<tr><td rowspan="10">6(a)</td><td colspan="2">Horizontal equation of motion</td><td>M1</td></tr>
<tr><td colspan="2">$$T\sin\theta = \frac{mrg}{a}$$</td><td>A1</td></tr>
<tr><td>Use triangle AOP to form an equation in θ, r, a and x

</td><td>Use triangle AOP to form an equation in θ, r and OP

</td><td>M1</td></tr>
<tr><td>Eg
• $\sin\theta = \dfrac{r}{a+x}$</td><td>Eg
• $\sin\theta = \dfrac{r}{OP}$
• $r = OP\sin\theta$</td><td>A1</td></tr>
<tr><td>Use of HL with extension
$$T = \frac{3mgx}{a}$$</td><td>Use of HL with OP
$$T = \frac{3mg\left(OP-a\right)}{a}$$</td><td>M1</td></tr>
<tr><td>Eliminate θ and T</td><td>Eliminate θ and T</td><td>DM1</td></tr>
<tr><td>Eg
• $\dfrac{3mgx}{a}\left(\dfrac{r}{a+x}\right) = \dfrac{mgr}{a}$</td><td>Eg
• $\dfrac{3mg\left(OP-a\right)}{a}\left(\dfrac{r}{OP}\right) = \dfrac{mgr}{a}$</td><td>A1</td></tr>
<tr><td colspan="2">$$(OP =)\ \frac{3}{2}a \ *$$</td><td>A1*</td></tr>
<tr><td colspan="2"></td><td>(8)</td></tr>
<tr><td rowspan="5">6(b)</td><td colspan="2">Vertical equilibrium</td><td>M1</td></tr>
<tr><td colspan="2">$$"R" + T\cos\theta = mg$$</td><td>A1</td></tr>
<tr><td colspan="2">Use $T = \dfrac{3mg}{2}$ and $\cos\theta = \dfrac{1}{3}$ to find an expression for "R" in terms of m and g only</td><td>DM1</td></tr>
<tr><td colspan="2">$$(R =)\ \frac{1}{2}mg$$</td><td>A1</td></tr>
<tr><td colspan="2"></td><td>(4)</td></tr>
<tr><td rowspan="2">6(c)</td><td colspan="2">$\text{EPE} = \dfrac{3mg}{2a}\left(\dfrac{1}{2}a\right)^2 \quad \left(= \dfrac{3mga}{8}\right)$</td><td>B1</td></tr>
<tr><td colspan="2">Expression for sum of EPE and KE
KE of the form $\dfrac{1}{2}m\left(r\omega\right)^2$ with $\omega = \sqrt{\dfrac{g}{a}}$ and $r = \sqrt{\left(\dfrac{3a}{2}\right)^2 - \left(\dfrac{a}{2}\right)^2}$
$\left(r\omega = \sqrt{2ag}\right)$</td><td>M1</td></tr>
</table>

Question Number	Scheme	Marks
	$=\frac{1}{2}m\left(a\sqrt{2}\sqrt{\frac{g}{a}}\right)^2+\frac{3mg}{2a}\left(\frac{1}{2}a\right)^2$	A1
	$=\frac{11mga}{8}$	A1
		(4)
		(16)
	Notes for question 6	
6(a)		
M1	Horizontal equation of motion. All required terms and no extras. Condone sin/cos confusion. Acceleration does not need to be replaced. Accept any form of acceleration, $r\omega^2$ or $\frac{v^2}{r}$. Condone a for acceleration for this M mark only.	
A1	Correct equation with acceleration correctly replaced and correct radius. A0 if *OP* is the radius.	
M1	Use triangle *OPA* to form an equation in θ, r and **either** *OP* **or** a and x. Condone sin/cos confusion. (Pythagoras alone is M0)	
A1	Correct equation	
M1	Use of Hooke's Law in terms of extension or *OP*	
DM1	Dependent on all 3 previous M marks. Eliminate T and θ to produce an equation in m, g, a, r and either *OP* or x (r's may have been cancelled)	
A1	Correct equation	
A1*	Given answer obtained from complete and correct working. Condone missing *OP*. Accept $\frac{3}{2}a$, $\frac{3a}{2}$.	
6(b)		
M1	Method using vertical equilibrium. All required terms present and no extras. Condone sign errors and sin/cos confusion. If seen in part (a), it must be used in (b) to earn the marks. Note that R is not defined in the question, may use another letter or even the wording from the question.	
A1	Correct unsimpified equation.	
DM1	Dependent on previous M. Substitute for T and $\cos\theta$ to obtain an expression for "R" in terms of m and g only.	
A1	Correct answer in terms of m and g	
6(c)		
B1	Correct expression for EPE	
M1	Method to find total, KE + EPE. Must have terms added together and not just listed. Required terms only. Dimensionally correct expression with energy terms of the correct structure. KE term, must use $v=r\omega$ with $\omega=\sqrt{\frac{g}{a}}$ and $r=\sqrt{\left(\frac{3a}{2}\right)^2-\left(\frac{a}{2}\right)^2}$	
A1	Correct unsimplified expression.	
A1	Correct answer. Must be simplified to one term in m, g and a. Accept $1.375mga$, $1.38\,mga$, $1.4\,mga$.	

<table>
<tr><th>Question Number</th><th colspan="2">Scheme</th><th>Marks</th></tr>
<tr><td rowspan="7">7(a)</td><td>General equation of motion for particle, measuring up from E.

$T-\frac{3mg}{2}=\frac{3m\ddot{x}}{2}$</td><td>General equation of motion for particle, measuring down from E.

$\frac{3mg}{2}-T=\frac{3m\ddot{x}}{2}$</td><td>M1</td></tr>
<tr><td>Use HL in equation of motion with extension $\left(\frac{3L}{8}\pm x\right)$</td><td>Use HL in equation of motion with extension $\left(\frac{3L}{8}\pm x\right)$</td><td>DM1</td></tr>
<tr><td>Correct equation
$\frac{4mg}{L}\left(\frac{3L}{8}-x\right)-\frac{3mg}{2}=\frac{3m\ddot{x}}{2}$</td><td>Correct equation
$\frac{3mg}{2}-\frac{4mg}{L}\left(\frac{3L}{8}+x\right)=\frac{3m\ddot{x}}{2}$</td><td>A1</td></tr>
<tr><td colspan="2">Complete conclusion
$-\frac{8g}{3L}x=\ddot{x} \quad \therefore \quad SHM \ *$</td><td>A1*</td></tr>
<tr><td colspan="2">Identify ω from SHM method and use to find the Period</td><td>DM1</td></tr>
<tr><td colspan="2">$\omega^2=\frac{8g}{3L}$ or $\omega=\sqrt{\frac{8g}{3L}}$
Period = $\frac{2\pi}{\omega}=2\pi\sqrt{\frac{3L}{8g}}=\pi\sqrt{\frac{3L}{2g}}$ *</td><td>A1*</td></tr>
<tr><td colspan="2"></td><td>(6)</td></tr>
<tr><td rowspan="3">7(b)</td><td colspan="2">Correct amplitude, $a=\frac{1}{2}L$</td><td>B1</td></tr>
<tr><td colspan="2">Use of SHM displacement equation with amplitude substituted. No need to substitute for ω.
[1] $x=-a\cos\omega t$
[2] $x=a\cos\omega t$
[3] $x=a\sin\omega t$
[4] $x=-a\sin\omega t$</td><td>M1</td></tr>
<tr><td colspan="2">Complete method to find an equation for a relevant time. No need to substitute for ω.

Either
Use $\ddot{x}=-\omega^2 x$ with $-\frac{2g}{3}$ to find displacement. May start again with N2L, HL and $-\frac{2g}{3}$ to find displacement. Must then combine displacement of $\pm\frac{L}{4}$ with one of [1], [2], [3] or [4] above to form an equation in t (and ω).</td><td>M1</td></tr>
</table>

Question Number	Scheme	Marks
	Or Substitute $-\frac{2g}{3}$ and their a in the corresponding acceleration equation to form an equation in t (and ω) [1] $\ddot{x} = a\omega^2\cos(\omega t)$ [2] $\ddot{x} = -a\omega^2\cos(\omega t)$ [3] $\ddot{x} = -a\omega^2\sin(\omega t)$ [4] $\ddot{x} = a\omega^2\sin(\omega t)$	
	Dependent on both previous M marks. Complete method to find the required time. Where appropriate, must use the correct proportion of the given period to find an expression for the required time. Must use the correct ω. [1] $t = \frac{1}{\omega}\times\cos^{-1}\left(-\frac{1}{2}\right)$ [2] $t = \frac{1}{\omega}\cos^{-1}\left(\frac{1}{2}\right) - \frac{\text{period}}{2} \quad = \frac{5\pi}{3\omega} - \frac{\text{period}}{2}$ [3] $t = \frac{1}{\omega}\sin^{-1}\left(\frac{1}{2}\right) + \frac{\text{period}}{4} = \frac{\text{period}}{4} + \frac{\pi}{6\omega}$ [4] $t = \frac{1}{\omega}\sin^{-1}\left(-\frac{1}{2}\right) - \frac{\text{period}}{4} \quad = \frac{7\pi}{6\omega} - \frac{\text{period}}{4}$	DM1
	$t = \frac{2\pi}{3}\sqrt{\frac{3L}{8g}}$ o.e.	A1
		(5)
		(11)
	Notes for question 7	
7(a)		
M1	Equation of motion in a *general* position ie T does not take a particular value. Allow a for acceleration here. Required terms present with no extras. Condone sign errors but must have a difference between T and weight. Condone missing $\frac{3}{2}$ in 'ma' term only for this mark.	
DM1	Dependent on previous M. Use of Hooke's Law in a *general* equation of motion with general position measured from E. Extension in HL must be of the appropriate form: $\left(\frac{3L}{8} - x\right)$ or $\left(\frac{3L}{8} + x\right)$. Allow a for acceleration, condone sign errors. Must use the correct mass, $\frac{3m}{2}$ in 'ma' term.	
A1	For a fully correct unsimplified equation. Must use $\ddot{x}$ for acceleration.	

Question Number	Scheme	Marks
A1*	Correct SHM equation and conclusion. Equation must have required form, $\ddot{x} = -\omega^2 x$ with $\ddot{x}$ for acceleration. Conclusion must include 'SHM'	
DM1	Dependent on both previous M's. Use of $\frac{2\pi}{\omega}$ where ω has come from an attempt at using N2L at a general point.	
A1*	Obtain the given answer for the period. Must follow from complete and correct working. At least one line of working must be seen between $\ddot{x} = -\frac{8g}{3L}x$ and reaching the given Period. Eg • period = $\frac{2\pi}{\omega} = \frac{2\pi}{\sqrt{\frac{8g}{3L}}} = \pi\sqrt{\frac{3L}{2g}}$ • $\omega = \sqrt{\frac{8g}{3L}}$, period = $\frac{2\pi}{\omega} = \pi\sqrt{\frac{3L}{2g}}$ Note The score of M1 DM1 A1 A0* DM1 A1* is possible if there is no conclusion of 'SHM' The score of M1 DM1 A0 A0* DM1 A1* is possible if $\ddot{x}$ is not used for acceleration.	
7(b)		
B1	Correct amplitude, $\frac{L}{2}$.	
M1	Use of suitable SHM equation with their amplitude substituted. May be implied if starting with a corresponding velocity or acceleration equation. No need to replace ω.	
M1	All necessary steps completed to find an equation for a relevant time. No need to replace ω.	
DM1	Complete method to find an expression for the **required** time. Must use the correct ω.	
A1	Correct value for required time in **exact** form, in terms of L and g e.g. $\frac{2\pi}{3}\sqrt{\frac{3L}{8g}}$, $\frac{\pi}{3}\sqrt{\frac{3L}{2g}}$, $\pi\sqrt{\frac{L}{6g}}$, $\frac{\pi}{6}\sqrt{\frac{6L}{g}}$	

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