Mark Scheme (Results)

January 2018

Pearson Edexcel
International Advanced Subsidiary 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: Method marks are awarded for 'knowing a method and attempting to apply it', unless otherwise indicated.
- **A** marks: Accuracy marks can only be awarded if the relevant method (M) marks have been earned.
- **B** marks are unconditional accuracy marks (independent of M marks)
- Marks should not be subdivided.

3. 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
   - o.e. – or equivalent (and appropriate)
   - d… or dep – dependent
   - indep – independent
   - dp decimal places
   - sf significant figures
   - $\ast$ The answer is printed on the paper or ag- answer given
   - $\lfloor$ or d… 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.

Jan 2018 IAL
WME03 M3
Mark Scheme

Question Number	Scheme	Marks
1.	cone cylinder S	
	Mass $\frac{1}{3}\pi r^2 \times 4h$ $\pi r^2 \times 3h$ $\frac{13}{3}\pi r^2 h$ 4 9 13	B1
	Dist $(-)h$ $\frac{3}{2}h$ $\bar{x}$	B1
	$-4h+\frac{27}{2}h=13\bar{x}$	M1A1ft
	$\bar{x}=\frac{19}{26}h \ (=0.73h \text{ or better})$	A1
		[5]
B1 **B1** **M1** **A1ft** **A1**	Correct mass ratio, any equivalent form Correct distances from any point Attempt to form a moments equation with their mass ratios and distances. If distances are measured from O there must be a difference of mass x distance terms Correct equation, follow through their mass ratios and distances but must be dimensionally correct Correct answer. Must be positive.	

Question Number	Scheme	Marks
2	$\dfrac{29.4(y-1.2)^2}{2\times1.2}=0.9\times9.8y$	M1A1A1
	$y^2-3.12y+1.44=0$	
	$y=\dfrac{3.12\pm\sqrt{3.12^2-4\times1.44}}{2}$, $y=2.556...=2.6$ or 2.56 (m)	DM1A1 (5) **[5]**
M1	Attempt an energy equation with a GPE term and a single EPE term of the form $k\dfrac{\lambda x^2}{l}$	
A1	Either term correct	
A1	Both terms correct	
DM1	Obtain a 3 term quadratic and attempt its solution. Formula to be correct (if shown). This mark can only be awarded for a calculator solution if final answer is correct.	
A1cao	Correct distance *AB*. Second solution for quadratic need not be shown.	
ALT:	$\dfrac{29.4x^2}{2\times1.2}=0.9\times9.8(x+1.2)$ etc (solves to 1.356...) Second M mark here requires completion to distance *AB*	M1A1A1

If SUVAT (or energy) used to natural length, the first M mark is for the energy equation with a single EPE term, a KE term and a GPE term.
Award A1 for any 2 terms correct and A1 for third term correct.
The second M mark is for solving and completing to required distance

Question Number	Scheme	Marks
3 (a)	$0.4\dfrac{\mathrm{d}v}{\mathrm{d}t}=-\dfrac{8}{(t+4)^2}$	M1
	$v=\int -\dfrac{20}{(t+4)^2}\,\mathrm{d}t$	
	$v=\dfrac{20}{(t+4)}\ (+c)$	DM1A1
	$t=0,\ v=10\Rightarrow\ 10=5+c,\ c=5$	DM1
	$v=\dfrac{20}{(t+4)}+5$ *	A1cso (5)
(b)	$x=\int \dfrac{20}{(t+4)}+5\ \mathrm{d}t$	
	$x=20\ln(t+4)+5t+c$	M1A1
	$t=0,\ x=0\Rightarrow 0=20\ln 4+c\quad c=-20\ln 4$	A1
	$v=6\quad \dfrac{20}{t+4}=1\quad t=16$	B1
	$x=20\ln 20+80-20\ln 4=80+20\ln 5$	
	$a=80,\ b=20$	A1cao (5) **[10]**
(a)	0.4 or m for the mass for the first 4 marks	
M1	Form an equation of motion with the acceleration in form shown. Minus sign may be missing.	
DM1	Attempt the integration	
A1	Correct integration, including correct sign. Constant not needed	
DM1	Use $t=0,\ v=10$ to obtain a value for c	
A1cso	Correct answer only, no errors seen	
(b)		
M1	Integrate the **given** expression for v to obtain an expression for x. Constant not needed.	
A1	Correct integration, constant not needed	
A1	Obtain the correct constant	
B1	Correct value for t when $v = 6$	
A1cao	Correct values for a and b Need not be shown explicitly.	
	By definite integration:	
(a)	M1 DM1 as above A1 as above but limits not needed here DM1 Substitute correct limits A1 cao no errors seen	
(b)	M1A1 as above but limits not needed here A1 Substitute lower limit (0) to obtain $-20\ln 4$ B1A1 as above	

Question Number	Scheme	Marks
4	$(4a)^2 + r^2 = (8a-r)^2$, Radius $=3a$	M1,A1
	$T\cos\theta = mg - R$	M1A1
	$T + T\sin\theta = m \times \text{rad} \times \omega^2$ $\frac{8}{5}T = 3ma\omega^2$	M1A1A1
	$2mg - 2R = 3ma\omega^2$	DM1
	$R \geq 0 \quad 2mg - 3ma\omega^2 \geq 0 \quad \omega^2 \leq \frac{2g}{3a}$	M1A1
	$S \geqslant 2\pi\sqrt{\frac{3a}{2g}}, = \pi\sqrt{\frac{6a}{g}}$ *	DM1,A1cso
		[12]

M1	Attempt to obtain the radius, probably using Pythagoras. Can be done by justifying eg 3 + 5 = 8 so 3,4,5 triangle
A1	Correct radius seen here or used *providing* the M mark has been awarded.
M1	Resolve vertically, 3 forces in the equation with T resolved
A1	Correct equation with $\cos\theta$ or $\frac{4}{5}$
M1	Equation of motion along the horizontal radius, T must be resolved, their radius or r allowed, acceleration in either form. Allow if T_A and T_B used
A1	Forces correct, $\sin\theta$ or $\frac{3}{5}$ Both tensions to be the same
A1	Acceleration correct in form shown, their radius or r
DM1	Eliminate T and replace trig functions with their values if not done earlier. This is a M mark, so trig functions need not be correct. Depends on 2nd and 3rd M marks but **not the first**.
M1	Use $R \geq 0$ to obtain an inequality for ω^2
A1	Correct inequality Must use $r = 3a$ now or later.
DM1	Use period $= \frac{2\pi}{\omega}$ to obtain an inequality for S (or different letter if used). Direction of the inequality must change. Depends on previous M mark.
A1cso	Correct inequality **as shown in the question** obtained from correct and complete working **NB Candidates who assume a 3,4,5 triangle without showing any working or justification will lose the first 2 marks and this one.** If R not seen **and work done with equations** mark as above: M1A1M0A0M1A1A1M0M0A0M0A0 Max available. **If inequalities** used from start in the vertical resolution statement **mark as below:**

Question Number	Scheme	Marks
	Alternative, combines second and fifth M marks	
	$(4a)^2 + r^2 = (8a-r)^2$, Radius $= 3a$	M1,A1
	$T\cos\theta \le mg$	M1A1 M1(5th on e-pen)
	$T + T\sin\theta = m \times \text{rad} \times \omega^2$ $\frac{8}{5}T = 3ma\omega^2$	M1A1A1
	$2mg \ge 3ma\omega^2$	DM1A1
	$S \geqslant 2\pi\sqrt{\frac{3a}{2g}}, = \pi\sqrt{\frac{6a}{g}}$ *	DM1,A1cso [12]
M1	Attempt to obtain the radius, probably using Pythagoras. Can be done by justifying eg 3 + 5 = 8 so 3,4,5 triangle	
A1	Correct radius seen here or used *providing* the M mark has been awarded.	
M1	Resolve vertically, using $R \ge 0$ Allow with inequality in the wrong direction.	
M1	5th on e-PEN Correct direction for inequality	
A1	Correct inequality with $\cos\theta$ or $\frac{4}{5}$	
M1	Equation of motion along the horizontal radius, T must be resolved, their radius or r allowed, acceleration in either form. Allow if T_A and T_B used	
A1	Forces correct, $\sin\theta$ or $\frac{3}{5}$ Both tensions to be the same	
A1	Acceleration correct in form shown, their radius or r	
DM1	Eliminate T and replace trig functions with their values if not done earlier. This is a M mark, so trig functions need not be correct. Depends on 2nd and 3rd M marks but **not the first or 5th**.	
A1	Correct inequality Must use $r = 3a$ now or later.	
DM1	Use period $= \frac{2\pi}{\omega}$ to obtain an inequality for S (or different letter if used). Direction of the inequality must change. Depends on previous M mark.	
A1cso	Correct inequality **as shown in the question** obtained from correct and complete working **NB Candidates who assume a 3,4,5 triangle without showing any working or justification will lose the first 2 marks and this one.**	

Question Number	Scheme	Marks
5(a)	$\text{Vol} = \pi\int_0^{\frac{\pi}{2}} y^2\text{d}x = \pi\int_0^{\frac{\pi}{2}} \sin^2 x\text{d}x$	M1
	$=(\pi)\int_0^{\frac{\pi}{2}} \frac{1}{2}(1-\cos 2x)\text{d}x$	M1
	$=\frac{\pi}{2}\left[x-\frac{1}{2}\sin 2x\right]_0^{\frac{\pi}{2}} = \frac{\pi^2}{4}$ *	DM1A1cso (4)
(b)	$\pi\int_0^{\frac{\pi}{2}} y^2 x\,\text{d}x = \pi\int_0^{\frac{\pi}{2}} x\sin^2 x\,\text{d}x$	M1
	$=\pi\int_0^{\frac{\pi}{2}} \frac{1}{2}x(1-\cos 2x)\text{d}x = \frac{\pi}{2}\left[\frac{x^2}{2}\right]_0^{\frac{\pi}{2}} - \frac{\pi}{2}\int_0^{\frac{\pi}{2}} x\cos 2x\,\text{d}x$	
	$=-\frac{\pi}{2}\left[x\times\frac{1}{2}\sin 2x\right]_0^{\frac{\pi}{2}} + \frac{\pi}{2}\int_0^{\frac{\pi}{2}}\frac{1}{2}\sin 2x\,\text{d}x, + \frac{\pi^3}{16}$	M1,B1
	$=0-\frac{\pi}{2}\left[\frac{1}{4}\cos 2x\right]_0^{\frac{\pi}{2}} + \frac{\pi^3}{16}$	DM1
	$=-\frac{\pi}{8}[-1-1]+\frac{\pi^3}{16} = \frac{\pi^3}{16}+\frac{\pi}{4}$	A1
	$\bar{x} = \frac{\pi^3+4\pi}{16} \div \frac{\pi^2}{4} = \frac{\pi^2+4}{4\pi}$	M1A1cso (7) **[11]**
ALT(b)	$\pi\int_0^{\frac{\pi}{2}} y^2 x\,\text{d}x = \pi\int_0^{\frac{\pi}{2}} x\sin^2 x\,\text{d}x$	M1
	$=\pi\left[\frac{x}{2}\left(x-\frac{1}{2}\sin 2x\right)\right]_0^{\frac{\pi}{2}} - \pi\int\frac{1}{2}\left(x-\frac{1}{2}\sin 2x\right)\text{d}x$	M1
	$=\frac{\pi^3}{8}, -\frac{\pi}{2}\left[\frac{x^2}{2}+\frac{1}{4}\cos 2x\right]_0^{\frac{\pi}{2}}$	B1,DM1
	$=\frac{\pi^3}{8}-\frac{\pi}{2}\left[\frac{\pi^2}{8}-\frac{1}{4}-\frac{1}{4}\right] = \frac{\pi^3}{16}+\frac{\pi}{4}$	A1
	$\bar{x} = \frac{\pi^3+4\pi}{16} \div \frac{\pi^2}{4} = \frac{\pi^2+4}{4\pi}$	M1A1cso (7)

Question Number	Scheme	Marks
	NB: Beware of incorrect signs for trig functions which become 0 on substitution of the limits.	
(a)		
M1	Forming the required integral, limits not needed. π needed for this mark but may be seen at end (see NB below)	
M1	Using $\sin^2\theta = k(1 \pm \cos 2\theta)$ with $k = \pm\frac{1}{2}$ or ± 2 limits not needed, π not needed	
M1	Integration of their function and substitution of correct limits. π may be missing. Must have used $\sin^2\theta = k(1 \pm \cos 2\theta)$ or $\sin^2\theta = k(1 \pm \sin 2\theta)$ with any value of k	
A1cso	Correct **given** result with no errors in the solution.	
NB:	If π missing, but appears suddenly at the end with no explanation given, only M0M1M1A0 available. If explanation for inc. π is given, all marks are available. Look for $V = \pi\int y^2 \mathrm{d}x$ somewhere if π missing initially.	
(b)	The first 5 marks are available for the integration w/wo π	
M1	Use $\int y^2 x \,\mathrm{d}x$ limits not needed	
M1	Attempt integration by parts (first stage) for any multiple of $x\cos 2x$ or $x\sin 2x$ or by using their result for $\int \sin^2 x \,\mathrm{d}x$ from (a), limits not needed $\cos 2x \to \pm\frac{1}{2}\sin 2x$ or $\sin 2x \to \pm\frac{1}{2}\cos 2x$	
B1	For $\frac{\pi^3}{16}$ (or $\frac{\pi^2}{16}$ if working the integration without π) Using the result from (a) gets this mark for $\frac{\pi^3}{8}$ or $\frac{\pi^2}{8}$	
DM1	Completing the integration. Depends on the second M mark. Same condition on integration of trig function.	
A1	Substituting the correct limits to obtain $\frac{\pi^3}{16} + \frac{\pi}{4}$ or $\frac{\pi^2}{16} + \frac{1}{4}$	
M1	Using $\bar{x} = (\pi)\int y^2 x \,\mathrm{d}x \div (\pi)\int y^2 \mathrm{d}x$. π must be included for both integrals or neither. Denominator: to be the result given in (a). Numerator: Some attempt to obtain (by algebraic integration) a value for this integral must have been made and their value used here.	
A1cso	$(\pi^2 + 4)/4\pi$ any equivalent (in terms of π) accepted	

1

Question Number	Scheme	Marks
6 (a)	$\frac{1}{2}\times mv^2-\frac{1}{2}\times m\times 2lg=mgl\cos\theta$	M1A1
	$T-mg\cos\theta=m\frac{v^2}{l}$	M1A1A1
	$T=mg\cos\theta+\frac{1}{l}\left(2mgl\cos\theta+2mgl\right)$	DM1
	$T=mg\left(3\cos\theta+2\right)$ *	A1cso (7)
(b)	$T=0\Rightarrow\cos\theta=-\frac{2}{3}$	B1
	$v^2=-gl\cos\theta$ or $v^2=2gl\cos\theta+2gl$	
	$v^2=\frac{2gl}{3}$, $v=\sqrt{\frac{2gl}{3}}$	M1,A1 (3)
(c)	Horiz speed at $B=v\lvert\cos\theta\rvert=\sqrt{\frac{2gl}{3}}\times\frac{2}{3}$	M1A1ft on v
	Energy: $\frac{1}{2}m\left(\frac{2gl}{3}\right)-\frac{1}{2}m\times\frac{4}{9}\left(\frac{2gl}{3}\right)=mgh$	M1
	$h=\frac{5l}{27}$	A1
	Height above O $=\frac{5l}{27}+l\cos\left(180-\theta\right)=\frac{5l}{27}+\frac{2l}{3}=\frac{23l}{27}$ (0.85l or 0.852l)	A1 cao (5) **[15]**
ALT(c)	Vert speed at $B=v\cos\left(\theta-90\right)=v\sin\theta=\sqrt{\frac{2gl}{3}}\times\frac{\sqrt{5}}{3}$	M1A1ft on v
	$0=\frac{2gl}{3}\times\frac{5}{9}-2gs$	M1
	$s=\frac{5l}{27}$	A1
	Height above O $=\frac{5l}{27}+l\cos\left(180-\theta\right)=\frac{5l}{27}+\frac{2l}{3}=\frac{23l}{27}$	A1 (5)

Question Number	Scheme	Marks
(a)		
M1	Forming an **energy** equation from start to the general position. 2 KE terms needed and a change in PE (with 1 or 2 terms)	
A1	Correct equation	
M1	Attempting an equation of motion along the radius at the general position. Weight must be resolved. Acceleration can be in either form.	
A1	Correct difference of forces	
A1	Acceleration as shown	
DM1	Eliminate v^2 between the 2 equations. Depends on both previous M marks. Working must be shown.	
A1cso	Obtain the given expression for T with no errors in the solution.	
(b)		
B1	$\cos\theta = -\frac{2}{3}$ (at point where string becomes slack)	
M1	Obtaining v^2 or v in terms of g and l	
A1	Correct expression for v, any equivalent form	
(c)		
M1	Resolve their speed at B to obtain the horizontal component	
A1ft	$\frac{2}{3}\times$ their speed	
M1	Attempting an energy equation from B to the highest point, 2 non-zero KE terms needed	
A1	Obtain the correct height above B	
A1cao	Complete to the correct height above O	
ALT(c)		
M1	Resolve their speed at B to obtain the vertical component	
A1ft	$\frac{\sqrt{5}}{3}\times$ their speed	
M1	Use $v^2 = u^2 + 2as$ with their (non-zero) u and $v = 0$ to obtain the height above B	
A1	Obtain the correct height above B	
A1	Complete to the correct height above O	

Question Number	Scheme	Marks
7(a)	$\dfrac{20e}{1.8}=\dfrac{15(1.5-e)}{0.9}$	M1A1
	$2e=4.5-3e \quad e=\dfrac{4.5}{5}=0.9$	A1
	$AO=2.7\,\text{m}$ *	A1cso (4)
ALT	With AO as unknown: $\dfrac{20(AO-1.8)}{1.8}=\dfrac{15(4.2-AO-0.9)}{0.9}$ M1A1A1	
	$AO=2.7\,\text{m}$ * A1cso	
(b)	$\dfrac{15(0.6-x)}{0.9}-\dfrac{20(0.9+x)}{1.8}=m\ddot{x}$ or $\dfrac{20(0.9-x)}{1.8}-\dfrac{15(0.6+x)}{0.9}=m\ddot{x}$	M1A1A1
	$-\dfrac{50}{1.8m}x=\ddot{x}$ oe	M1
	$(m>0)$ $\therefore$ SHM	A1cso (5)
(c)	$-\dfrac{50}{1.8\times10}x=\ddot{x}$	
	$\omega=\sqrt{\dfrac{50}{18}}\ \left(=\dfrac{5}{3}\right)$	B1ft
	$a=0.2\,\text{m}$	B1
	$v_{\max}=a\omega=0.2\times\dfrac{5}{3}$	M1
(i)	$J=10\times0.2\times\dfrac{5}{3}=\dfrac{10}{3}\ (=3.3...\ =3.3 \text{ or better})$	M1A1
	$x=-0.1$	
(ii)	$-0.1=0.2\sin t\left(\dfrac{5}{3}\right)$	M1
	$t=\dfrac{3}{5}\sin^{-1}(-0.5)=\dfrac{3}{5}\times\dfrac{7\pi}{6}=2.199...\,\text{s}$ (accept 2.2 or better inc $\dfrac{7\pi}{10}$)	M1A1 (8)
		[17]

1

Question Number	Scheme	Marks
(a)		
M1	Attempt an equation equating 2 tensions. Tensions to be obtained using Hooke's Law. The two extensions must add to 1.5	
A1	Correct equation	
A1	Correct extension for either string	
A1cso	Correct completion to length AO	
(b)		
M1	Form an equation of motion with the difference of 2 tensions with different variable extensions. Tensions must be of the form $k\frac{\lambda x}{l}$. Acceleration can be $\ddot{x}$ or a.	
	NB: x can be measured in either direction.	
A1 A1	Deduct one per error (Award A1A0 for one deduction.)	
	Allow if a used instead of $\ddot{x}$ **provided** the direction of a is the same as that of $\ddot{x}$	
M1	Attempt to simplify their equation to the standard form for SHM. Acceleration must be $\ddot{x}$ now. Equation must simplify to $\ddot{x} = \pm\,\omega^2 x$	
A1cso	Correct equation with conclusion.	
(c)		
B1ft	Correct value of ω, seen explicitly or used. Follow through from their equation of the form $\ddot{x}$ or $a = \pm\omega^2 x$ If equation has been left in the form $m\ddot{x}$ or $ma = ...$ in (b) but RHS divided by m here to obtain ω this mark is available (but no extra marks for (b)).	
B1	Correct amplitude, seen explicitly or used	
M1	Attempt the maximum speed with their a and ω	
(i)M1	Use an impulse-momentum equation with their max speed to obtain a value for J	
A1	Correct value for J	
(ii)M1	Use $x = a\sin\omega t$ or $x = a\cos\omega t$ with $x = \pm 0.1$, their ω and a	
M1	Solve their equation and use a correct method to find the required time. Must use radians	
A1	Correct time 2.2 or better	

1