Pearson

Mark Scheme (Final)

January 2026

Pearson Edexcel International Advanced Level
In Mechanics M3 (WME03) Paper 01A

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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.

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 and can be used if you are using the annotation facility on ePEN.
   - 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)
   - d… or dep – dependent
   - indep – independent
   - dp decimal places
   - sf significant figures
   - ∗ The answer is printed on the paper or ag- answer given
   - ⌐ 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. If you are using the annotation facility on ePEN, indicate this action by ‘MR’ in the body of the script.

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

*(**N.B.** specific mark schemes may sometimes override these general principles)*

- Rules for M marks:
  - correct number of terms
  - dimensionally correct
  - all terms that need resolving (i.e. *multiplied* by cos or sin) are resolved
  - only terms that need resolving are resolved
  - +/– errors are condoned
  - sin/cos confusion is condoned
- 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(s) has been awarded.
- Any numerical answer which comes from use of g = 9.8 should be given as a decimal 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

1. A particle P of mass 0.5 kg moves along the positive x-axis under the action of a single force of magnitude F newtons.

The force acts along the x-axis in the direction of x increasing.

When P is x metres from the origin O, it is moving away from O with

speed $\sqrt{\left(8x^{\frac{3}{2}} - 4\right)}\ \mathrm{m\,s^{-1}}$

Find F when P is 4 m from O.

(5)

(Total for Question 1 is 5 marks)

Question Number	Scheme			Marks
1	A complete method to find acceleration by differentiating v or v^2			M1
	Method 1	Method 2	Method 3	
	$v^2 = 8x^{\frac{3}{2}} - 4$ $2v\dfrac{dv}{dx} = 12x^{\frac{1}{2}}$ $v\dfrac{dv}{dx} = 6x^{\frac{1}{2}}$	$\dfrac{dv}{dx} = \dfrac{1}{2}\left(8x^{\frac{3}{2}} - 4\right)^{-\frac{1}{2}} \times 12x^{\frac{1}{2}}$ $v\dfrac{dv}{dx} = \dfrac{1}{2} \times 12x^{\frac{1}{2}}$	$\dfrac{dv}{dt} = \dfrac{1}{2}\left(8x^{\frac{3}{2}} - 4\right)^{-\frac{1}{2}} \times 12x^{\frac{1}{2}} \times \dfrac{dx}{dt}$ $\dfrac{dv}{dt} = \dfrac{1}{2}\left(8x^{\frac{3}{2}} - 4\right)^{-\frac{1}{2}} \times 12x^{\frac{1}{2}} \times \left(8x^{\frac{3}{2}} - 4\right)^{\frac{1}{2}}$	A1 A1
	$F = 0.5 \times 6x^{\frac{1}{2}} = 3x^{\frac{1}{2}}$			DM1
	$x = 4 \Rightarrow F = 6$			A1
				(5)
				(5 marks)

Notes

M1	Complete method to find acceleration by differentiating in terms of x Must use correct form of acceleration (E.g. $\dfrac{dv}{dt} = \dfrac{1}{2}\left(8x^{\frac{3}{2}} - 4\right)^{-\frac{1}{2}} \times 12x^{\frac{1}{2}}$ is M0)
A1	Differentiation of their method with at most one numerical error (E.g. fraction or sign error)
A1	Correct acceleration i.e. correct derivative used or for example "acceleration =" Could be implied by correct value used in $F = ma$
DM1	Use of $F = 0.5a$ to obtain an expression in terms of x (seen or implied). Dependent on first M1.
A1	Cao

2. A spacecraft S of mass m moves in a straight line towards the centre of the Earth.

The Earth is modelled as a sphere of radius R and S is modelled as a particle.

When S is at a distance x, $x \geqslant R$, from the centre of the Earth, the force exerted by the Earth on S is directed towards the centre of the Earth.

The force has magnitude $\frac{K}{x^2}$, where K is a constant.

(a) Show that $K = mgR^2$

(2)

When S is at a distance $3R$ from the centre of the Earth, the speed of S is V.

Assuming that air resistance can be ignored,

(b) find, in terms of g, R and V, the speed of S as it hits the surface of the Earth.

(7)

(Total for Question 2 is 9 marks)

Question Number	Scheme	Marks
2(a)	$mg = \frac{K}{R^2}$	M1
	$K = mgR^2$ *	A1*
		(2)
(b)	Equation of motion: $\frac{mgR^2}{x^2} = -mv\frac{\mathrm{d}v}{\mathrm{d}x}$	M1
	Integrate: $g\int \frac{R^2}{x^2}\,\mathrm{d}x = -\int v\,\mathrm{d}v$	DM1
	$-g\frac{R^2}{x} = -\frac{1}{2}v^2 \quad (+c)$	A1ft
	Initial conditions: $x = 3R,\ v = V \Rightarrow -g\frac{R^2}{3R} = -\frac{1}{2}V^2 + c$	M1
	$c = -\frac{Rg}{3} + \frac{1}{2}V^2$	A1
	$\frac{1}{2}v^2 = -\frac{Rg}{3} + \frac{1}{2}V^2 + g\frac{R^2}{R}$	M1
	$v = \sqrt{V^2 + \frac{4Rg}{3}}$	A1
		(7)
		(9 marks)

Notes

(a) M1	Sets "F" = mg **and** $x = R$
A1*	Deduces given answer from correct working only with no errors seen. Do not allow recovery from an erroneous negative sign. Condone e.g. $F = mg = \frac{K}{x^2}$ followed by $mg = \frac{K}{R^2}$ Allow use of $F = \frac{GMm}{x^2}$ with $x = R$ and $F = mg$ as part of correct working.
(b) M1	Attempts equation of motion with acceleration in the form $v\frac{\mathrm{d}v}{\mathrm{d}x}$. Allow without minus sign.
DM1	Separates the variables and attempts to integrate. Dependent on first M1.
A1ft	Correct integration but ft missing minus sign. Condone missing constant of integration.
M1	Substitutes $x = 3R$, $v = V$ to form an equation for c.
A1	Correct expression for c seen or implied or $3R$ and V correctly substituted
M1	Substitute $x = R$ and find expression for v or v^2.
A1	cao

Alt (b) M1	Attempts equation of motion with acceleration in the form $v\dfrac{\mathrm{d}v}{\mathrm{d}x}$. Allow without minus sign.
DM1	Separates the variables and attempts to integrate. Dependent on first M1.
A1ft	Correct integration but ft missing minus sign.
M1	Definite integration with limits 3*R* and *R*, *V* and "*v*" $\left[g\dfrac{R^2}{x}\right]_{3R}^{R}=\left[\dfrac{1}{2}v^2\right]_{V}^{v} \quad\Rightarrow\quad \left[gR-\dfrac{gR}{3}\right]=\left[\dfrac{1}{2}v^2-\dfrac{1}{2}V^2\right]$
A1	Correct substitution of 3*R* and *V* seen or implied
M1	Substitute $x = R$ and find expression for v or v^2.
A1	Cao

Alt (b) M1	Forms work-energy equation. Allow without minus sign.
DM1	$\dfrac{1}{2}mv^2-\dfrac{1}{2}mV^2=-\displaystyle\int_{3R}^{R}\dfrac{mgR^2}{x^2}\,\mathrm{d}x$.
A1ft	Correct integration $\dfrac{1}{2}v^2-\dfrac{1}{2}V^2=\left[\dfrac{gR^2}{x}\right]_{3R}^{R}$
M1	Definite integration with 3*R* and *R* correct way round
A1	Correct substitution of 3*R* seen or implied and k.e. right way round
M1	Substitute $x = R$ and find expression for v or v^2. $\dfrac{1}{2}v^2=\dfrac{1}{2}V^2+\dfrac{gR^2}{R}-\dfrac{gR^2}{3R}$
A1	cao

3. A particle P is moving in a straight line with simple harmonic motion about the fixed point O as centre.

When P is a distance 0.02 m from O, the speed of P is $0.3\,\text{m}\,\text{s}^{-1}$ and the magnitude of the acceleration of P is $0.5\,\text{m}\,\text{s}^{-2}$

(a) Find the period of the motion.

(4)

The amplitude of the motion is a metres.

Find

(b) the value of a,

(3)

(c) the total length of time during each complete oscillation for which P is within $\frac{1}{2}a$ metres of O.

(4)

(Total for Question 3 is 11 marks)

Question Number	Scheme		Marks
3(a)	$\ddot{x} = -\omega^2 x \Rightarrow (\pm)0.5 = (\pm)0.02\omega^2$		M1
	$\omega = 5$		A1
	$T = \frac{2\pi}{\omega}$		M1
	$\frac{2\pi}{5}$ (s)		A1
			(4)
(b)	$v^2 = \omega^2\left(a^2 - x^2\right)$		M1
	$0.3^2 = "\omega^2"\left(a^2 - 0.02^2\right)$		A1ft
	$a = \frac{\sqrt{10}}{50}$ (m)		A1
			(3)
(c)	$x = a \sin \omega t$	$x = a \cos \omega t$	M1
	$t = \frac{1}{\omega}\sin^{-1}\left(\frac{1}{2}\right) = \frac{\pi}{30}$	$t = \frac{1}{\omega}\cos^{-1}\left(\frac{1}{2}\right) = \frac{\pi}{15}$	A1
	Time = $4 \times \frac{\pi}{30}$	Time = $"\frac{2\pi}{5}" - 4 \times \frac{\pi}{15}$	DM1
	$\frac{2\pi}{15}$ (s)		A1
			(4)
			(11 marks)

Notes

(a) M1	Uses $\ddot{x}$ or $a = -\omega^2 x$ with $\ddot{x} = 0.5$ and $x = 0.02$ to form an equation for ω^2. Condone sign errors.
A1	Obtains correct value for ω or ω^2 from correct working ie no sign errors (E.g. $\omega^2 = -25$ leading to $\omega = 5$ scores M1A0)
M1	Use of $T = \frac{2\pi}{\omega}$ with their value of ω
A1	Accept 1.3 or better (1.256637061…) N.B. it is possible to score M1A0M1A1 in part (a)
(b) M1	Use of $v^2 = \omega^2(a^2 - x^2)$ with $v = 0.3$, $x = 0.02$ and their ω Must be correct substitution (e.g. not ω or T or a instead of ω^2)
A1ft	Correct equation, follow through their ω
A1	Accept 0.063 or better (0.0632455532…)
(c) M1	Use of $x = a\sin\omega t$ or $x = a\cos\omega t$ with their ω and $x = \pm\frac{1}{2}a$. May see a or their value substituted.
A1	Correct time from centre or end (0.1047… or 0.2094…)
DM1	Correct method to find the required time. Depends on first M1.
A1	Accept 0.42 or better (0.4188790205…)

4. A light elastic string has natural length 5 m and modulus of elasticity 20 N.

The ends of the string are attached to two fixed points A and B, which are 6 m apart on a horizontal ceiling.

A particle P is attached to the midpoint of the string and hangs in equilibrium at a point which is 4 m below AB.

(a) Calculate the weight of P.

(6)

The particle is now raised to the midpoint of AB and released from rest.

(b) Calculate the speed of P when it has fallen 4 m.

(5)

(Total for Question 4 is 11 marks)

Question Number	Scheme	Marks
4(a)	Length of string/half string = 10 m / 5 m (or extension = 5 m / 2.5 m)	B1
	Hooke's Law	M1
	$T = \frac{\lambda x}{l} = \frac{20\times 5}{5}, \quad = 20$	A1
	Resolve vertically	M1
	$2\times "20"\times \frac{4}{5} = W$	A1ft
	Weight = 32 (N)	A1
		(6)
(b)	Conservation of Energy	M1
	$\frac{1}{2}"m"v^2 = "32"\times 4 - \left(\frac{20\times 5^2}{2\times 5} - \frac{20\times 1^2}{2\times 5}\right)$	A1ft A1ft
	Substitute $m = \frac{32}{9.8}$ and solve	DM1
	$v = 7$ (m s^{-1})	A1
		(5)
		(11 marks)

Notes

(a) B1	Correct length of complete or half string or correct extension(s) (seen or implied)
M1	Apply Hooke's law. Condone mixed approach (E.g. two strings with $x = 2.5$ but $l = 5$)
A1	Correct tension seen or implied
M1	Resolving vertically. Must have both tensions. Condone sin/cos confusion.
A1ft	Correct equation with their tension substituted. Allow *mg* for weight.
A1	Cao (allow labelling as *mg* and isw if they give an answer of 32 but go on to find *m*)
(b) M1	Energy Equation with all four terms. Condone sin/cos confusion and sign errors. The equation must be dimensionally correct.
A1ft	Unsimplified equation with at most one error. Ft their *W* or *m* and allow with *W* or *mg*. An incorrect natural length or missing 2 on the denominator of both epe terms is one error.
A1ft	Correct equation. Ft their *W* or *m* and allow with *W* or *mg*
DM1	Substitutes their mass (not weight) into their equation. Dependent on first M1 in (b).
A1	Cao (7, 7.0 or 7.00 only)

5. **In this question you must show all stages of your working.**
Solutions relying on calculator technology are not acceptable.

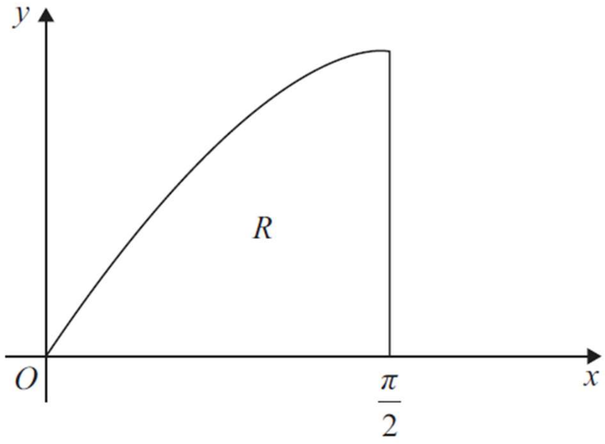

Figure 1

Figure 1 shows the finite region R which is bounded by part of the curve with equation $y = \sin x$, the x-axis and the line with equation $x = \frac{\pi}{2}$

A uniform solid S is formed by rotating R through 2π radians about the x-axis.

Using algebraic integration,

(a) show that the volume of S is $\frac{\pi^2}{4}$

(4)

(b) find, in terms of π, the x coordinate of the centre of mass of S.

(7)

(Total for Question 5 is 11 marks)

Question Number	Scheme	Marks
5(a)	Volume = $\pi\int_0^{\frac{\pi}{2}} y^2\,\mathrm{d}x = \pi\int_0^{\frac{\pi}{2}} \sin^2 x\,\mathrm{d}x$	M1
	$= \pi\int_0^{\frac{\pi}{2}} \frac{1}{2}(1-\cos 2x)\,\mathrm{d}x$	M1
	$= \pi\left[\frac{x}{2}-\frac{1}{4}\sin 2x\right]_0^{\frac{\pi}{2}} = \pi\left[\left(\frac{\pi}{4}-\frac{1}{4}\sin\pi\right)-\left(0-\frac{1}{4}\sin 0\right)\right]$	DM1
	$=\frac{\pi^2}{4}$ *	A1*
		(4)
(b)	$\pi\int_0^{\frac{\pi}{2}} y^2 x\,\mathrm{d}x = \pi\int_0^{\frac{\pi}{2}} x\sin^2 x\,\mathrm{d}x$	M1
	Method 1: Double angle formula then integration by parts: $\pi\int_0^{\frac{\pi}{2}} \frac{x}{2}\mathrm{d}x - \pi\int_0^{\frac{\pi}{2}} \frac{1}{2}x\cos 2x\,\mathrm{d}x$	
	$= \left(\pi\left[\frac{x^2}{4}\right]_0^{\frac{\pi}{2}}\right) - \pi\left[\frac{x}{2}\times\frac{1}{2}\sin 2x\right]_0^{\frac{\pi}{2}} + \pi\int_0^{\frac{\pi}{2}}\frac{1}{2}\times\frac{1}{2}\sin 2x\,\mathrm{d}x$	M1
	$=\frac{\pi^3}{16}\left(-\pi[0-0]-\pi\left[\frac{1}{8}\cos 2x\right]_0^{\frac{\pi}{2}}\right)$	B1
	$=\left(\frac{\pi^3}{16}\right)-\frac{\pi}{8}[\cos\pi-\cos 0]$	DM1
	Method 2: Integration by parts using result from part (a): $=\pi\left[\frac{x}{2}\left(x-\frac{1}{2}\sin 2x\right)\right]_0^{\frac{\pi}{2}} - \pi\int_0^{\frac{\pi}{2}}\frac{1}{2}\left(x-\frac{1}{2}\sin 2x\right)\mathrm{d}x$	M1
	$=\frac{\pi^3}{8}\left(-\pi\left[\frac{x}{4}\sin 2x\right]_0^{\frac{\pi}{2}}-\pi\left[\frac{x^2}{4}+\frac{1}{8}\cos 2x\right]_0^{\frac{\pi}{2}}\right)$	B1
	$=\left(\frac{\pi^3}{8}\right)-\pi\left([\sin\pi-\sin 0]+\left[\frac{\pi^2}{16}+\frac{1}{8}\cos\pi-\frac{1}{8}\cos 0\right]\right)$	DM1
	$=\frac{\pi^3}{16}+\frac{\pi}{4}$	A1
	Complete method to find $\bar{x}$	DM1
	$\bar{x}=\dfrac{\frac{\pi^3+4\pi}{16}}{\frac{\pi^2}{4}}=\frac{\pi^2+4}{4\pi}$	A1
		(7)

	(11 marks)
Notes	
(a) M1	Forms the required integral, limits not needed but need to see π or justification at end.
M1	Use of $\sin^2\theta = k(1 \pm \cos 2\theta)$ with $k = \pm\frac{1}{2}$ or ± 2. Limits not needed. π not needed.
DM1	Integration of their function and substitution of correct limits. π may be missing. Integration requires powers of x to increase and sin/cos to become cos/sin. Depends on the first M mark only.
A1*	cso. Penalise incorrect signs on trig functions which become 0 on substitution of the limits. If π is missing but appears only in the last line can only score maximum M0M1M1A0. If explanation for inclusion of π is given all marks are available.
	N.B. the first 5 marks in (b) are available with or without π in front of the integration
(b) M1	Use of $\int y^2 x \, dx$ (limits not needed)
M1	Integration by parts of $x\cos 2x$, or of $x\sin^2 x$ using result from (a), with "u" = kx
B1	Correct integration of polynomial part: $\frac{\pi^3}{16}$ or $\frac{\pi^3}{8}$ (or $\frac{\pi^2}{16}$ or $\frac{\pi^2}{8}$ without π) or equivalent seen or implied.
DM1	Completing the integration. Dependent on the previous M mark.
A1	Correct integration seen or implied N.B. without limits the integral is $\frac{x^2}{4} - \frac{x}{4}\sin 2x - \frac{1}{8}\cos 2x \quad (+c)$
DM1	Use of $\bar{x} = \frac{(\pi)\int y^2 x \, dx}{(\pi)\int y^2 \, dx}$. π must be included for both integrals or neither. Dependent on second M mark i.e. must have attempted integration by parts. Denominator must be the given result from (a) (allow correctly cancelled π) Numerator must use their value.
A1	Cso. Accept any equivalent exact form. N.B. Question specifies need for algebraic working, so e.g. $\pi\int_0^{\frac{\pi}{2}} x\sin^2 x \, dx = \frac{\pi^3}{16} + \frac{\pi}{4}$ followed by answer with no algebraic working would score M1M0B0M0A0M0A0.

6 The path followed by a motorcycle round a circular racetrack is modelled as a horizontal circle of radius 50 m. The track is banked at an angle θ to the horizontal, where $\sin\theta = \frac{3}{5}$. The motorcycle travels round the track at constant speed.

The motorcycle is modelled as a particle and air resistance can be ignored.

In an initial model it is assumed that there is no sideways friction between the motorcycle tyres and the track.

Using this model,

(a) find the speed, in $\mathrm{m\,s^{-1}}$, of the motorcycle.

(5)

In a refined model it is assumed that there is sideways friction.

The coefficient of friction between the motorcycle tyres and the track is $\frac{1}{4}$

It is still assumed that air resistance can be ignored and that the motorcycle is modelled as a particle.

The motorcycle's path is unchanged.

Using this model,

(b) find the maximum speed, in $\mathrm{m\,s^{-1}}$, at which the motorcycle can travel without slipping sideways.

(8)

(Total for Question 6 is 13 marks)

Question Number	Scheme	Marks
6(a)	Resolve Vertically $R\cos\theta = mg$	B1
	Resolve Horizontally	M1
	$R\sin\theta = \frac{mv^2}{r}$	A1ft
	$\tan\theta = \frac{3}{4} = \frac{v^2}{50g} \Rightarrow v = ...$	DM1
	$v = 19$ (m s^{-1})	A1
		(5)
(b)	Resolve Vertically	M1
	$R\cos\theta - F\sin\theta = mg$	A1
	Resolve Horizontally	M1
	$R\sin\theta + F\cos\theta = \frac{mv^2}{r}$	A1 A1
	$F = \frac{1}{4}R$	B1
	Solve for v	DM1
	$v = 25$ (m s^{-1})	A1
		(8)
		(13 marks)

Notes

(a) B1	Resolve vertically; correct equation only.
M1	Equation of motion horizontally: allow any form for acceleration and condone sin/cos confusion. Award if their "R" is $mg\cos\theta$ but M0 for "R" = mg
A1ft	Correct equation. Ft their "R". N.B. The first three marks can be awarded for the equation $mg\tan\theta = \frac{mv^2}{r}$
DM1	Substitute for trig ratios and reach $v^2 = \ldots$ or $v = \ldots$ Dependent on previous M mark.
A1	19 or 19.2 only
(b) M1	Resolve vertically. Must have all terms but condone sign errors and sin/cos confusion. M0 for use of their R from part (a)
A1	Correct unsimplified equation
M1	Resolve horizontally. Must have all terms but condone sign errors and sin/cos confusion. M0 for use of their R from part (a)
A1	Unsimplified equation with at most one error. Acceleration must be in correct form.
A1	Correct unsimplified equation
B1	Use of $F = \frac{1}{4}R$ where R is the normal reaction in part (b) (E.g. not their R from (a), not mg, not $mg\cos\theta$) Must be substituted into an equation.
DM1	Eliminate R and F to form equation in v. Dependent on both previous M marks.
A1	25 or 24.6 only

Alt (a)	For first three marks: resolve parallel to track $mg\sin\theta = \frac{mv^2}{r}\cos\theta$ M1 for both terms (condone sin/cos confusion); B1 one term correct, A1 both correct.
Alt (b)	For first 5 marks, resolve parallel and perpendicular to track: $F + mg\sin\theta = m\left(\frac{v^2}{r}\right)\cos\theta$ $R - mg\cos\theta = m\left(\frac{v^2}{r}\right)\sin\theta$ Score "best" equation seen as M1A1A1 and second equation as M1A1

7.

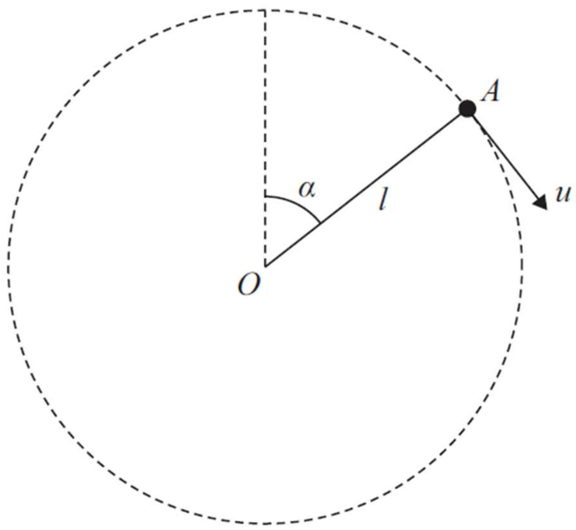

Figure 2

A particle of mass m is attached to one end of a light rod of length l. The other end of the rod is attached to a fixed point O. The rod can turn freely in a vertical plane about a horizontal axis through O.

The particle is projected with speed u from a point A, where OA makes an angle α with the upward vertical through O, as shown in Figure 2.

The particle moves in complete vertical circles.

Given that $\cos\alpha = \frac{4}{5}$

(a) show that $u > \sqrt{\frac{2gl}{5}}$

(4)

As the rod rotates, the least tension in the rod is T and the greatest tension is $4T$.

(b) Show that $u = \sqrt{\frac{17}{5}gl}$

(11)

(Total for Question 7 is 15 marks)

Question Number	Scheme	Marks
7(a)	For complete circles there must be speed at the top	B1
	Energy with ke > 0 at top $\frac{1}{2}mv^2 = \frac{1}{2}mu^2 - mg(l - l\cos\theta) > 0$	M1
	$\frac{1}{2}mu^2 > \frac{mgl}{5}$	A1
	$u > \sqrt{\frac{2gl}{5}}$ *	A1*
		(4)
(b)	Equation of motion at bottom	M1
	$T_{max} - mg = m\frac{v_{max}^2}{l}$	A1
	Energy equation to bottom	M1
	$\frac{1}{2}mv_{max}^2 = \frac{1}{2}mu^2 + mgl(1+\cos\alpha)$	A1
	$T_{max} = \frac{mu^2}{l} + \frac{18mg}{5} + mg$ $\left(\text{or } T_{min} = \frac{mu^2}{l} - \frac{2mg}{5} - mg\right)$	A1
	Equation of motion at top	M1
	$T_{min} + mg = m\frac{v_{min}^2}{l}$	A1
	Energy equation to top	M1
	$\frac{1}{2}mv_{min}^2 = \frac{1}{2}mu^2 - mgl(1-\cos\alpha)$	A1
	$T_{max} = 4 \times T_{min}$	M1
	$u = \sqrt{\frac{51gl}{15}} = \sqrt{\frac{17gl}{5}}$ *	A1*
		(11)
		(15 marks)

Notes

(a) B1	Or equivalent statement seen or implied by working. Condone $v \geqslant 0$. N.B. this is a rod so $T > 0$ is B0.
M1	Uses energy and $v > 0$ to form an inequality for u^2 If v is not explicitly seen then inequality must be justified by speed at top being positive. Use of equality followed by given answer without clear justification of the inequality is M0.
A1	Correct inequality (allow $\geqslant$ for this mark)
A1*	Deduces given result with no incorrect working seen. Allow consistent omission of m throughout.
(b) M1	Equation of motion at lowest point. Condone sign errors.
A1	Correct equation.
M1	Energy equation to lowest point. Condone sign errors and sin/cos confusion.
A1	Correct equation.
A1	Eliminates v to get expression for tension in terms of m, g, l, u only. Award for correct expression for T_{max} or T_{min} seen or implied.
M1	Equation of motion at highest point. Condone sign errors.

A1	Correct equation. A0 if same velocity used for both equations of motion unless recovered later.
M1	Energy equation to highest point. Condone sign errors and sin/cos confusion.
A1	Correct equation. Award if energy equation from (a) is used in (b) A0 if same velocity used for both energy equations unless recovered later.
	N.B. Either energy equation could be replaced by an energy equation for top to bottom: $\frac{1}{2}mv_{\text{max}}{}^2 = \frac{1}{2}mv_{\text{min}}{}^2 + 2mgl$
M1	Compares the two tensions with 4 on the right side. This could be awarded if, e.g. *T* and 4*T* are used the right way round in the equations of motion.
A1*	Obtains given answer with no incorrect working seen (condone missing brackets and recovery from poor notation (e.g. both velocities as *v*) but not recovery of incorrect minus signs). Must see some working after the four equations of energy / motion.
	N.B. Some useful values: $T_{\text{max}} = 8mg$ $T_{\text{min}} = 2mg$ $v_{\text{max}} = 7gl$ $v_{\text{min}} = 3gl$

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