GCE

Further Mathematics B MEI

Y421/01: Mechanics major

A Level

Mark Scheme for June 2024

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This mark scheme is published as an aid to teachers and students, to indicate the requirements of the examination. It shows the basis on which marks were awarded by examiners. It does not indicate the details of the discussions which took place at an examiners' meeting before marking commenced.

All examiners are instructed that alternative correct answers and unexpected approaches in candidates' scripts must be given marks that fairly reflect the relevant knowledge and skills demonstrated.

Mark schemes should be read in conjunction with the published question papers and the report on the examination.

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MARKING INSTRUCTIONS

PREPARATION FOR MARKING
RM ASSESSOR

1. Make sure that you have accessed and completed the relevant training packages for on-screen marking: *RM Assessor Online Training*; *OCR Essential Guide to Marking*.

2. Make sure that you have read and understood the mark scheme and the question paper for this unit. These are posted on the RM Cambridge Assessment Support Portal http://www.rm.com/support/ca

3. Log-in to RM Assessor and mark the **required number** of practice responses ("scripts") and the **number of required** standardisation responses.

MARKING

1. Mark strictly to the mark scheme.

2. Marks awarded must relate directly to the marking criteria.

3. The schedule of dates is very important. It is essential that you meet the RM Assessor 50% and 100% (traditional 40% Batch 1 and 100% Batch 2) deadlines. If you experience problems, you must contact your Team Leader (Supervisor) without delay.

4. If you are in any doubt about applying the mark scheme, consult your Team Leader by telephone or the RM Assessor messaging system, or by email.

5. **Annotations**

Annotation	Meaning
✓and ✗	
BOD	Benefit of doubt
FT	Follow through
ISW	Ignore subsequent working
M0, M1	Method mark awarded 0, 1
A0, A1	Accuracy mark awarded 0, 1
B0, B1	Independent mark awarded 0, 1
E	Explanation mark 1
SC	Special case
^	Omission sign
MR	Misread
BP	Blank Page
Seen	
Highlighting	

Other abbreviations in mark scheme	Meaning
E1	Mark for explaining a result or establishing a given result
dep*	Mark dependent on a previous mark, indicated by *. The * may be omitted if only one previous M mark
cao	Correct answer only
oe	Or equivalent
rot	Rounded or truncated
soi	Seen or implied
www	Without wrong working
AG	Answer given
awrt	Anything which rounds to
BC	By Calculator
DR	This question included the instruction: In this question you must show detailed reasoning.

6. **Subject Specific Marking Instructions**

a. Annotations must be used during your marking. For a response awarded zero (or full) marks a single appropriate annotation (cross, tick, M0 or ^) is sufficient, but not required.

For responses that are not awarded either 0 or full marks, you must make it clear how you have arrived at the mark you have awarded and all responses must have enough annotation for a reviewer to decide if the mark awarded is correct without having to mark it independently.

It is vital that you annotate standardisation scripts fully to show how the marks have been awarded.

Award NR (No Response)
- if there is nothing written at all in the answer space and no attempt elsewhere in the script
- OR if there is a comment which does not in any way relate to the question (e.g. 'can't do', 'don't know')
- OR if there is a mark (e.g. a dash, a question mark, a picture) which isn't an attempt at the question.

Note: Award 0 marks only for an attempt that earns no credit (including copying out the question).

If a candidate uses the answer space for one question to answer another, for example using the space for 8(b) to answer 8(a), then give benefit of doubt unless it is ambiguous for which part it is intended.

b. An element of professional judgement is required in the marking of any written paper. Remember that the mark scheme is designed to assist in marking incorrect solutions. Correct solutions leading to correct answers are awarded full marks but work must not always be judged on the answer alone, and answers that are given in the question, especially, must be validly obtained; key steps in the working must always be looked at and anything unfamiliar must be investigated thoroughly. Correct but unfamiliar or unexpected methods are often signalled by a correct result following an apparently incorrect method. Such work must be carefully assessed. When a candidate adopts a method which does not correspond to the mark scheme, escalate the question to your Team Leader who will decide on a course of action with the Principal Examiner.

If you are in any doubt whatsoever you should contact your Team Leader.

c. The following types of marks are available.

M

A suitable method has been selected and applied in a manner which shows that the method is essentially understood. Method marks are not usually lost for numerical errors, algebraic slips or errors in units. However, it is not usually sufficient for a candidate just to indicate an intention of using

some method or just to quote a formula; the formula or idea must be applied to the specific problem in hand, e.g. by substituting the relevant quantities into the formula. In some cases the nature of the errors allowed for the award of an M mark may be specified.
A method mark may usually be implied by a correct answer unless the question includes the DR statement, the command words “Determine” or “Show that”, or some other indication that the method must be given explicitly.

A
Accuracy mark, awarded for a correct answer or intermediate step correctly obtained. Accuracy marks cannot be given unless the associated Method mark is earned (or implied). Therefore M0 A1 cannot ever be awarded.

B
Mark for a correct result or statement independent of Method marks.

E
A given result is to be established or a result has to be explained. This usually requires more working or explanation than the establishment of an unknown result.

Unless otherwise indicated, marks once gained cannot subsequently be lost, e.g. wrong working following a correct form of answer is ignored. Sometimes this is reinforced in the mark scheme by the abbreviation isw. However, this would not apply to a case where a candidate passes through the correct answer as part of a wrong argument.

d. When a part of a question has two or more ‘method’ steps, the M marks are in principle independent unless the scheme specifically says otherwise; and similarly where there are several B marks allocated. (The notation ‘dep*’ is used to indicate that a particular mark is dependent on an earlier, asterisked, mark in the scheme.) Of course, in practice it may happen that when a candidate has once gone wrong in a part of a question, the work from there on is worthless so that no more marks can sensibly be given. On the other hand, when two or more steps are successfully run together by the candidate, the earlier marks are implied and full credit must be given.

e. The abbreviation FT implies that the A or B mark indicated is allowed for work correctly following on from previously incorrect results. Otherwise, A and B marks are given for correct work only – differences in notation are of course permitted. A (accuracy) marks are not given for answers obtained from incorrect working. When A or B marks are awarded for work at an intermediate stage of a solution, there may be various alternatives that are equally acceptable. In such cases, what is acceptable will be detailed in the mark scheme. If this is not the case please, escalate the question to your Team Leader who will decide on a course of action with the Principal Examiner.

Sometimes the answer to one part of a question is used in a later part of the same question. In this case, A marks will often be 'follow through'. In such cases you must ensure that you refer back to the answer of the previous part question even if this is not shown within the image zone. You may find it easier to mark follow through questions candidate-by-candidate rather than question-by-question.

f. Unless units are specifically requested, there is no penalty for wrong or missing units as long as the answer is numerically correct and expressed either in SI or in the units of the question. (e.g. lengths will be assumed to be in metres unless in a particular question all the lengths are in km, when this would be assumed to be the unspecified unit.)
We are usually quite flexible about the accuracy to which the final answer is expressed; over-specification is usually only penalised where the scheme explicitly says so.
- When a value is given in the paper only accept an answer correct to at least as many significant figures as the given value.
- When a value is not given in the paper accept any answer that agrees with the correct value to 2 s.f. unless a different level of accuracy has been asked for in the question, or the mark scheme specifies an acceptable range.
  NB for Specification A the rubric specifies 3 s.f. as standard, so this statement reads "3 s.f".

Follow through should be used so that only one mark in any question is lost for each distinct accuracy error.
Candidates using a value of 9.80, 9.81 or 10 for g should usually be penalised for any final accuracy marks which do not agree to the value found with 9.8 which is given in the rubric.

g. Rules for replaced work and multiple attempts:
- If one attempt is clearly indicated as the one to mark, or only one is left uncrossed out, then mark that attempt and ignore the others.
- If more than one attempt is left not crossed out, then mark the last attempt unless it only repeats part of the first attempt or is substantially less complete.
- if a candidate crosses out all of their attempts, the assessor should attempt to mark the crossed out answer(s) as above and award marks appropriately.

h. For a genuine misreading (of numbers or symbols) which is such that the object and the difficulty of the question remain unaltered, mark according to the scheme but following through from the candidate's data. A penalty is then applied; 1 mark is generally appropriate, though this may differ for some units. This is achieved by withholding one A or B mark in the question. Marks designated as cao may be awarded as long as there are no other errors.
If a candidate corrects the misread in a later part, do not continue to follow through. E marks are lost unless, by chance, the given results are established by equivalent working. Note that a miscopy of the candidate's own working is not a misread but an accuracy error.

i. If a calculator is used, some answers may be obtained with little or no working visible. Allow full marks for correct answers, provided that there is nothing in the wording of the question specifying that analytical methods are required such as the bold “In this question you must show detailed reasoning”, or the command words “Show” or “Determine”. Where an answer is wrong but there is some evidence of method, allow appropriate method marks. Wrong answers with no supporting method score zero. If in doubt, consult your Team Leader.

j. If in any case the scheme operates with considerable unfairness consult your Team Leader.

Question	Answer	Marks	AO	Guidance
1 (a)	$1200(1.5) = 1200v + 800v$	**M1**	**3.3**	CLM soi – correct number of terms but allow sign errors, and allow a slip in one value only
	$v = 0.9$	**A1** **[2]**	**1.1**	
1 (b)	$I = 800(0.9)$ or $-I = 1200(0.9) - 1200(1.5)$ or $-I = 1200(0.9 - 1.5)$	**M1**	**3.3**	Use of Impulse = change in momentum on either A or B (so must be using the correct mass(es)), correct number of terms using their v from part **(a)** but allow sign errors
	$I = 720$ (N s)	**A1** **[2]**	**1.1**	Final answer must be positive – but condone e.g. '$I = 1200(0.9) - 1200(1.5) = -720$ therefore 720' for full marks

Question	Answer	Marks	AO	Guidance
2 (a)	$2g = k(0.05)$	**M1**	**1.1**	Use of $F = kx$ with $F = 2g$ or $F = 2$ and correct extension (0.05) soi
	$k = 40g$ or 392 (N m^{-1})	**A1**	**2.2a**	
		[2]		
2 (b)	Energy stored = $\frac{1}{2}(k)(0.05)^2$	**M1**	**1.2**	Use of $E = \frac{1}{2}kx^2$ with correct extension (0.05) and their k from part **(a)** soi
	$= 0.05g$ or 0.49 (J)	**A1**	**1.1**	
		[2]		
2(c)	$[k] = \mathrm{MT}^{-2}$	**B1**	**2.5**	[M][T^{-2}] (or other incorrect forms) is **B0** but condone if replaced with the correct answer – must be using capital letters (so **MUST** be MT^{-2} and nothing else)
		[1]		
2(d)	$[v] = \mathrm{LT}^{-1}$	**B1**	**1.2**	soi – allow incorrect notation provided intention is clear
	$\mathrm{LT}^{-1} = \mathrm{M}^{\alpha}\mathrm{L}^{\beta}(\mathrm{MT}^{-2})^{\gamma}$	**M1**	**2.1**	Setting up an equation in M, L and T using their [k] from part **(c)** with [m], [v] and [a] all correct – allow incorrect notation provided intention is clear
	$\beta = 1$	**A1**	**1.1**	www (so must come from a correct equation)
	$\alpha = -0.5,\ \gamma = 0.5$	**A1**	**1.1**	www (so must come from a correct equation)
		[4]		

Question	Answer	Marks	AO	Guidance
3		M1*	2.1	Forming an equation which if simplified **would** lead to a three-term cubic equation in r with no r^2 term. Do not award this mark until $\bar{x}$ has been replaced with a linear expression in r or, if taking moments about G, zero. Condone absence of π throughout the question and for this mark allow inconsistent use of π
	$(\pi(0.5)^2 - \pi r^2) \times 2r = ...$	A1	3.4	Correct LHS (if taking moments about A, C, O or end-point)
	$0.5 \times \pi(0.5)^2 - r \times \pi r^2$	A1	1.1	Correct RHS – consistent with corresponding LHS **If** taking moments about G then award **A2** for a correct equation
	$r^3 - 0.5r + 0.125\ (= 0)$	M1dep*	1.1	Re-arranging to obtain a three-term cubic equation/expression in r only with no r^2 term (or with π in **every** term so use of π must now be consistent) - all terms must be on the same side. The correct value of r following from a correct equation (in any form) implies this (and the next) mark – **note below some valid method(s) that may lead to a quadratic equation in r (rather than a cubic)**
	$r = 0.309$	A1	2.2a	**BC** no rationale required for the rejection of the other values of r but must be clear that r takes only this value. Accept $\frac{-1+\sqrt{5}}{4}$ or awrt 0.309 or allow 0.31 www – note that the correct value of r can come from the equation $r^2 + 0.5r - 0.25 = 0$ (see below)
		[5]		

For reference:

$M(A): (\pi(0.5)^2 - \pi r^2) \times 2r = 0.5 \times \pi(0.5)^2 - r \times \pi r^2$

$M(C): (\pi(0.5)^2 - \pi r^2) \times r = (0.5 - r) \times \pi(0.5)^2 \quad (\Rightarrow (0.5-r)(0.5+r) \times r = 0.25 \times (0.5-r) \therefore (0.5+r) \times r = 0.25)$

$M(O): (\pi(0.5)^2 - \pi r^2) \times (2r - 0.5) = (0.5 - r) \times \pi r^2 \quad (\Rightarrow (0.5-r)(0.5+r) \times (2r-0.5) = (0.5-r) \times r^2 \ \therefore (0.5+r)(2r-0.5) = r^2)$

$M(G): 0 = (2r - 0.5) \times \pi(0.5)^2 - r \times \pi r^2$

M(end-point): $(\pi(0.5)^2 - \pi r^2) \times (1 - 2r) = 0.5 \times \pi(0.5)^2 - (1 - r) \times \pi r^2$

Question	Answer	Marks	AO	Guidance
4(a)	$2\times 3g\cos 25=...$	B1	3.3	Correct moment of the weight about A – **must be part of an equation** (so must be equal to $k\times R_P$ where $k\neq 0$) – might see $53.29...=k\times R_P$
	$\frac{1.5}{\sin 25}\times R_P$ **or** $(1.5\sin 25)\times R_P+\frac{1.5}{\tan 25}\times R_P\cos 25$	B1	3.1b	Correct moment of the normal contact force about A – **must be part of an equation** – might see $3.549...\times R_P=...$
	$R_P=15.0\,(\text{N})$	B1	1.1	15.0144710… allow awrt 15.0 or 15 www
		[3]		
4(b)	**SEE APPENDIX FOR ALTERNATIVES**	M1*	3.3	Attempt to resolve and equate either the vertical **or** horizontal forces (with correct number of terms) – allow sign errors and sin/cos mix – but must be using the correct angle – allow R (oe) for this mark **only**
	$F_A=R_P\sin 25$	A1FT	1.1	Using their value of R_P from part **(a)** (for reference if correct: $F_A=6.34538967...$) – must not be part of an inequality. The follow through is only on their value of R_P
	$R_A+R_P\cos 25=3g$	A1FT	1.1	Using their value of R_P from part **(a)** (for reference: if correct $R_A=15.79226793...$) – must not be part of an inequality. The follow through is only on their value of R_P
	$F_A\leqslant \mu R_A$	M1dep*	3.4	**Use of** either $F=\mu R$ or $F\leqslant \mu R$ **with their values** of F_A and R_A - allow this mark if earlier inequalities used when resolving forces. Their values of F_A and R_A must have come from equations with the correct number of relevant terms (so must have used components of R_P but not a weight component) but allow sin/cos mix and sign errors
	$\mu\geqslant 0.402$	A1	1.1	awrt 0.401 or awrt 0.402 or allow 0.40 www but not 0.4. Any upper limit is **A0**. Condone $\mu=0.40$ replaced with $\mu\geqslant 0.40$ oe www
		[5]		

Question	Answer	Marks	AO	Guidance
5(a)	$\frac{18000}{v} - 600 = 0$	M1	3.3	Use of $P = Dv$ and using N2L horizontally with correct number of terms (condone 18 for 18 000) – allow sign errors
	$v = 30\ (\text{m s}^{-1})$	A1 [2]	1.1	
5(b)	Change in KE = $\pm 0.5 \times 850 \times (18^2 - 15^2)$ $(= \pm 42\,075)$	B1	1.1	Correct expression for the change in KE – need not be simplified e.g. $\pm(137700 - 95625)$ - both terms could appear on different sides of their work-energy equation – using 30 (for one of the velocities) should **not** be treated as a **MR**
	Work done by the car = 18000×10 $(= 180\,000)$	B1	1.1	Need not be simplified
	Change in PE = $\pm 850g \times \frac{1}{40} \times d$ $(= \pm 208.25d)$	B1	1.1	Where d is the length of the hill – allow $\pm 850g \times d \times \sin(1.4(325...))$
	$0.5(850)(18^2 - 15^2) = 18000 \times 10 - 850g \times \frac{1}{40} \times d - 103000$	M1	3.4	Use of work-energy principle – dimensionally consistent with the correct number of relevant terms. Allow sin/cos mix on PE term and sign errors. If using $850gd$ for the PE then **M0** but do watch out for those who multiply their final answer by 40 (oe) as this could then imply the correct change in PE (and possibly this **M** mark too). Using 30 for one of the velocities is **M0**.
	$d = 168\,(\text{m})$	A1 [5]	1.1	167.7… awrt 168 (but not 170) www - any attempts to use N2L and SUVAT **only** scores no marks

Question	Answer	Marks	AO	Guidance
6	$(\mathbf{v}=)\begin{pmatrix} 2t+c \\ \frac{1}{2}t^2+c' \end{pmatrix}$	M1*	3.4	At least one integration correct, but must have two components; condone missing c, c' (and accept **i**, **j** form throughout) – condone $\mathbf{v}=\begin{pmatrix} 2t \\ \frac{1}{2}t^2 \end{pmatrix}+c$ (so the constant appearing as a scalar)
	$(\mathbf{v}=)\begin{pmatrix} 2t \\ \frac{1}{2}t^2-8 \end{pmatrix}$	A1	1.1	
	$(\mathbf{r}=)\begin{pmatrix} t^2+d \\ \frac{1}{6}t^3-8t+d' \end{pmatrix}$	M1dep*	1.1	At least one integration correct, (follow-through their **v**) but must have two components – condone missing d, d' - condone constant appearing as a scalar
	$(\mathbf{r}=)\begin{pmatrix} t^2 \\ \frac{1}{6}t^3-8t+32 \end{pmatrix}$	A1	1.1	
	Substitute $t=\sqrt{x}$ in equation for y	M1	2.5	Must be substituting $t=\sqrt{x}$ into a cubic equation/expression in t – **dependent on both previous M marks**
	$y=\frac{1}{6}x^{\frac{3}{2}}-8x^{\frac{1}{2}}+32$	A1	1.1	Must be $y=\ldots$ or any equivalent un-simplified form containing y (so must be an equation) – condone e.g. $y=\frac{1}{6}(\sqrt{x})^3-8(\sqrt{x})+\frac{96}{3}$ isw
		[6]		

Question	Answer	Marks	AO	Guidance
7(a)	Meets x-axis at (2, 0)	**B1**	**1.1**	soi (e.g. intercepts axis when $x = 2$ or as the top limit of an integral)
	Area of L is 4	**B1**	**1.1**	**BC** or from $\int_0^2 (x^3 - 3x^2 + 4)\,dx$
	Use of $4\bar{x} = \int xy\,dx$ or $4\bar{y} = \frac{1}{2}\int y^2 dx$	**M1**	**1.1a**	soi – either correct coordinate implies this mark. Must substitute correct equation for y which is $y = x^3 - 3x^2 + 4$ - integral limits not required for this mark and allow their area of L (which if correct is 4) but their area must be numerical
	$\bar{x} = 0.6$	**A1**	**1.1**	**BC**
	$\bar{y} = \frac{52}{35}$	**A1**	**1.1**	**BC** (1.485714…) allow awrt 1.49 www (but not just 1.5)
		[5]		

Question	Answer	Marks	AO	Guidance
7(b)	$\tan\alpha = \dfrac{0.6}{\left(\frac{52}{35}\right)} = \dfrac{21}{52} \Rightarrow \alpha = 21.9...$	**M1**	**3.1b**	Use of $\tan\alpha = \dfrac{\overline{x}}{\overline{y}}$ (or reciprocal) with their values from **(a)** **and** find corresponding value of α (to at least **2** sf rot) oe
	$30 > 21.9...$ or 22 so will topple	**A1**	**2.2a**	Correct angle (to at least **2** sf rot), comparison (or a correct argument) and 'will topple' **or** compare 0.57… with $\frac{21}{52}$
		[2]		
	Alternative Solution $\tan\alpha = \dfrac{\left(\frac{52}{35}\right)}{0.6} = \dfrac{52}{21} \Rightarrow \alpha = 68.0...$	**M1**		Use of $\tan\alpha = \dfrac{\overline{y}}{\overline{x}}$ (or reciprocal) and find corresponding value of α (to at least **2** sf rot) oe
	$68.0... + 30 (= 98.0...) > 90$ so will topple	**A1**		Correct angle (to at least **2** sf rot), comparison (oe) **or** could mention 'vertical' (oe), and 'will topple'
7(c)	$\tan\alpha = \dfrac{\left(\frac{52}{35}\right)}{0.6} = \dfrac{52}{21} \Rightarrow \alpha = 68.0...$	**M1**	**3.1b**	Use of $\tan\alpha = \dfrac{\overline{y}}{\overline{x}}$ (or reciprocal) with their values from part **(a)** and find corresponding value of α (to at least **2** sf rot) oe
	$68.0... > 30$ so will not topple	**A1**	**2.2a**	Correct angle (to at least **2** sf rot), comparison (or a correct argument) and 'will not topple' **or** compare 0.57… with $\frac{52}{21}$
		[2]		
	Alternative Solution $\tan\alpha = \dfrac{0.6}{\left(\frac{52}{35}\right)} = \dfrac{21}{52} \Rightarrow \alpha = 21.9...$	**M1**		Use of $\tan\alpha = \dfrac{\overline{x}}{\overline{y}}$ (or reciprocal) with their values from **(a)** and find corresponding value of α (to at least **2** sf rot) oe
	$21.9... + 30 (= 51.9...$ or $52) < 90$ so will not topple	**A1**		Correct angle (to at least **2** sf rot), comparison (oe) **or** could mention 'vertical' (oe), and 'will not topple'

Question	Answer	Marks	AO	Guidance
8(a)	$3mg = \frac{4mgx}{0.4}$	M1	3.3	Correct application of Hooke's law (or $3mg = \frac{4mg(x-0.4)}{0.4}$) soi
	Distance is 0.7 (m)	A1 [2]	1.1	cao
8(b)	$3mg - T = 3m\ddot{x}$	M1*	3.1b	Use of N2L with correct number of terms, allow sign errors and a slip in one mass (e.g. allow mass m on the RHS but not m on both sides) and allow a etc. for the acceleration – allow T for tension (or an incorrect expression for T)
	$3mg - \frac{4mg(0.3+x)}{0.4} = 3m\ddot{x}$	A1	1.1	oe – allow un-simplified and allow a for acceleration
	$\ddot{x} + \frac{10g}{3}x = 0$ which represents SHM	A1	2.1	Must be a comment that this is SHM and must be using $\ddot{x}$ or $\frac{\mathrm{d}^2x}{\mathrm{d}t^2}$ - allow $\ddot{x} = -\frac{10g}{3}x$
	Use of $2.5 = A\omega$	M1dep*	3.4	Must have substituted their value of ω from an equation of the form $\ddot{x} + \omega^2 x = 0$ (could be from $x = A\sin(\omega t)$ but must be equivalent to applying the equation $2.5 = A\omega$ with their ω)
	A = 0.437 (m)	A1 [5]	2.2b	Exact $\frac{5\sqrt{6}}{28}$ or awrt 0.437 or allow 0.44 www

8(c)	$\frac{1}{2}(3m)(2.5)^2 + \frac{4mg(0.3)^2}{2(0.4)} = ...$	**B1**	**3.1b**	**Setting PE as zero at the equilibrium position (A)** Correct initial KE and EPE terms added together (ignore the addition of any initial PE term as this is covered in the next mark)
	$3mg(0.7-d)$	**B1**	**1.1**	Correct change in PE – allow $3mgh$ only if $d = 0.7 - h$ implied by later working – to award the first two B marks there must be an equation that would lead to the correct answer – condone consistent omission of m throughout for full marks
	Smallest distance is 0.231 (m)	**B1** **[3]**	**1.1**	awrt 0.231 or allow 0.23 www
	Alternative solution 1			**Setting PE as zero at lowest point of motion**
	$\frac{4mg(0.3+A)^2}{2(0.4)} = ...$	**B1FT**		Correct EPE term using their A from part **(b)**
	$3mg(0.7+A-d)$	**B1FT**		Correct change in PE term using their A from part **(b)** – allow $3mgh$ only if $d = 0.7 + A - h$ implied by later working – to award the first two B marks there must be an equation that would lead to the correct answer following through their value of A (**provided their answer for d would be positive**) – condone consistent omission of m throughout for full marks
	Smallest distance is 0.231 (m)	**B1**		awrt 0.231 or awrt 0.232 or allow 0.23 www

	Alternative solution 2			
	$v^2 = \frac{10g}{3} \times (0.437^2 - 0.3^2)$	**B1FT***		Correct use of $v^2 = \omega^2(A^2 - x^2)$ with their ω and A from part **(b)** and $x = 0.3$ to find the speed or speed^2 when the string becomes slack – for reference if correct: $v = 1.81...$
	$0 = 1.81...^2 - 2g(0.4 - d)$	**B1dep***		Correct use of $v^2 = u^2 + 2as$ with $v = 0, a = -g$ and their initial speed (which if correct is 1.81…) which leads to a positive value of d only – allow $0 = 1.81...^2 - 2gh$ only if $d = 0.4 - h$ implied by later working
	Smallest distance is 0.231 (m)	**B1**		awrt 0.231 or awrt 0.232 or allow 0.23 www

Question	Answer	Marks	AO	Guidance
9(a)	$5g - 0.05v^2 = 5v\dfrac{\mathrm{d}v}{\mathrm{d}x}$	**M1**	**3.3**	Applying N2L with correct number of terms (allow sign errors but dimensionally correct) – allow $v\dfrac{\mathrm{d}v}{\mathrm{d}x}$ or $\dfrac{\mathrm{d}v}{\mathrm{d}t}$ only for a
	$980 - v^2 = 100v\dfrac{\mathrm{d}v}{\mathrm{d}x} \Rightarrow \left(\dfrac{100v}{980 - v^2}\right)\dfrac{\mathrm{d}v}{\mathrm{d}x} = 1$	**A1**	**1.1**	**AG –** www (so any errors seen is **A0**)
		[2]		
9(b)	When $x = 0$, $v^2 = 980\left(1 - \mathrm{e}^{-0.02(0)}\right) = 980(1-1) = 0$	**B1**	**3.4**	Confirming that $v = 0$ when $x = 0$ – as a minimum must show at least one step of working e.g. $v^2 = 980(1 - \mathrm{e}^0) = 0$ but **B0** for just 'when $x = 0$, $v = 0$' – showing that $v^2 = 0$ without explicitly mentioning that $v = 0$ is **B1**
	$2v\dfrac{\mathrm{d}v}{\mathrm{d}x} = \dfrac{980}{50}\mathrm{e}^{-0.02x}$	**M1***	**1.1**	Attempt to differentiate either v or v^2 **-** must be of the form $2v\dfrac{\mathrm{d}v}{\mathrm{d}x} = k\mathrm{e}^{-0.02x}$ where $k \neq -980$ (or equivalent if differentiating v) – if implying $2v\dfrac{\mathrm{d}v}{\mathrm{dt}} = k\mathrm{e}^{-0.02x}$ then **M0**
	$\dfrac{100\left(\dfrac{980}{100}\mathrm{e}^{-0.02x}\right)}{980 - (980 - 980\mathrm{e}^{-0.02x})}$	**M1dep***	**1.1**	Substitute their derivative and correct expression for v^2 into $\left(\dfrac{100v}{980 - v^2}\right)\dfrac{\mathrm{d}v}{\mathrm{d}x}$
	$\dfrac{980\mathrm{e}^{-0.02x}}{980\mathrm{e}^{-0.02x}} = 1$ (as required)	**A1**	**1.1**	**AG** so sufficient working must be shown (but no conclusion after arriving at '= 1' is required) – allow other complete methods to show that $\left(\dfrac{100v}{980 - v^2}\right)\dfrac{\mathrm{d}v}{\mathrm{d}x} = 1$ e.g. using $v^2 = 980(1 - \mathrm{e}^{-0.02x})$ to derive given de
		[4]		

	Alternative Solution			
	$x = \int \frac{100v}{980 - v^2} \mathrm{d}v = k \ln(980 - v^2)(+c)$	**M1***		Solve the given differential equation by separating variables and obtaining $x = k \ln(980 - v^2)$ or $x = k \ln\left\|980 - v^2\right\|$ with $k \neq 0$
	$x = -50 \ln(980 - v^2)\,(+c)$	**A1**		or $x = -50 \ln\left\|980 - v^2\right\|$ - condone lack of constant of integration
	$x = 0, v = 0 \Rightarrow 0 = -50 \ln 980 + c \ \therefore c = 50 \ln 980$	**M1dep***		Using correct initial conditions to find c
	$x = -50 \ln(980 - v^2) + 50 \ln 980$ $x = 50 \ln\left(\frac{980}{980 - v^2}\right)$ $\frac{980}{980 - v^2} = \mathrm{e}^{\frac{x}{50}} \Rightarrow 980 - v^2 = 980\mathrm{e}^{-\frac{x}{50}}$ $v^2 = 980(1 - \mathrm{e}^{-0.02x})$	**A1**		**AG** – sufficient working must be shown – at least one line of additional working from $x = -50 \ln(980 - v^2) + 50 \ln 980$ to given answer required – any errors is **A0**

9(c)	$980 - v^2 = 100(8.36) \Rightarrow v = ...$	**M1***	**3.1b**	Use N2L equation from part **(a)** (or re-start) with $a = 8.36$ to find v (if correct then $v = 12$) or v^2 – allow minor slips when solving for v only
	$x = 50\ln\left(\frac{980}{980 - 12^2}\right)$ (=7.946…)	**M1dep***	**3.1b**	Using the equation from part **(b)** to find the distance P falls from O to given point – dependent on the previous **M** mark – allow minor slips when solving for x only
	Loss in PE = $5g(7.946...)$	**B1FT**	**1.1**	Dependent on **both** previous **M** marks – **FT** their x
	Gain in KE = $\frac{1}{2}(5)(12)^2$ (= 360)	**B1FT**	**1.1**	Using their value of v – **dependent on the first M mark only – FT** their v
	Work done against resistance = 389.363… – 360 = 29.4 (J)	**A1**	**2.2a**	awrt 29.4 or awrt 29.6 (from using $x = 7.95$) or allow 29 www or allow 30 www (from using $x = 7.95$)
		[5]		
	Alternative Solution			
	$980 - v^2 = 100(8.36) \Rightarrow v = ...$	**M1***		Use N2L equation from part **(a)** (or re-start) with $a = 8.36$ to find v (if correct then $v = 12$) – allow minor slips when solving for v only
	$x = 50\ln\left(\frac{980}{980 - 12^2}\right)$ (=7.946…)	**M1dep***		Using the equation from part **(b)** to find the distance P falls from O to given point – allow minor slips when solving for x only
	Work done is $\int 0.05 \times 980(1 - e^{-0.02x})\,dx$	**B1***		Setting up correct integral – ignore limits for this mark
	$= 49(x + 50e^{-0.02x})$	**M1dep***		Integrate to get an expression of the form $k_1 x + k_2 e^{-0.02x}$ where k_1, k_2 are both non-zero – **this mark is dependent on the previous B mark only** – ignore limits for this mark – a correct answer implies this mark (as can be done **BC**)
	29.4 (J)	**A1**		awrt 29.4 or allow 29 www

Question	Answer	Marks	AO	Guidance
10	Time to collision is $\frac{5}{14}$ (= 0.35714…)	**B1**	**3.1b**	awrt 0.357 or allow 0.36 www
	Collision occurs at a distance 4.375 above the ground	**B1**	**3.1b**	This could appear at any stage of their working – or for 0.625 (distance that Q travels before collision)
	Before collision P's velocity: $\pm(14 - g \times \frac{5}{14})$ $(= \pm 10.5)$	**M1***	**3.3**	Use of $v = u + at$ with u = 14 and $a = \pm g$ and their t which must be less than 0.419 – if using $v^2 = u^2 + 2as$ their $s < 5$
	Before collision Q's velocity: $\pm(g \times \frac{5}{14})$ $(= \pm 3.5)$	**M1***	**1.1**	Using their $t < 0.419$ **or** from $v^2 = u^2 + 2as$ with $u = 0$, $a = +g$ and their $s < 5$
		M1dep*	**3.3**	Use of either CLM **or** NEL for the collision between P and Q (correct form (so e.g. e must be with the approach speed) and correct number of terms but allow sign errors)
	$2v_P + 8v_Q = 2(10.5) + 8(-3.5)$	**A1FT**	**1.1**	With their 10.5 and 3.5 (but must be different signs)
	$v_P - v_Q = -\frac{11}{14}(10.5 - (-3.5))$	**A1FT**	**1.1**	Consistent with CLM with their 10.5 and 3.5 – so must be considering $\pm(10.5 + 3.5)$ for their 10.5 and 3.5
	$v_P = -9.5, (v_Q = 1.5)$	**A1**	**1.1**	Only v_P required – allow positive value (9.5) www
	$4.375 = 9.5t + 0.5gt^2$	**M1**	**3.4**	Using $s = ut + 0.5at^2$ (oe) using correct 4.375 and their u to set up a 3TQ in t – **dependent on all previous M marks**. Allow wrong sign(s) for M mark
	t = 0.384 (s)	**A1**	**2.2a**	**BC** negative root need not be rejected but 0.384 must be their final answer – awrt 0.384 or allow 0.38 www
		[10]		

Question	Answer	Marks	AO	Guidance
11(a)	$1\times g\cos 20 = 1\times a$	**M1**	**3.3**	Use of $F = ma$ tangentially soi – allow without explicitly seeing $m = 1$ and award this mark for $m\times g\cos 20 = m\times a$ - condone sign errors and sin/cos mix **only**
	$a = 9.21\ (\text{m s}^{-2})$	**A1**	**1.1**	awrt 9.21or allow 9.2 www
		[2]		
11(b)	$32 - 1\times g\sin\theta = \dfrac{1\times v^2}{0.5}$	**M1***	**3.3**	Use of N2L radially – correct number of terms – allow sign errors and sin/cos mix - allow without explicitly seeing $m = 1$ stated/used– must be using $a = \frac{mv^2}{r}$ with correct values of m and r but allow T for 32 for this mark
	$\frac{1}{2}(1)(3.2)^2 = \frac{1}{2}(1)v^2 - 1(g)(0.5\sin\theta)$	**M1***	**1.1**	Use of conservation of energy (correct number of terms with $h = 0.5\sin\theta$ or $h = 0.5\cos\theta$ **only (**if taking the initial position as PE = 0)) – allow sign errors
	Substitute for v^2 in energy equation	**M1dep***	**3.4**	Or solve simultaneous equations in v^2 and $\sin\theta$ (oe) – all values must have been substituted for this mark
	$\frac{1}{2}(1)(3.2)^2 = \frac{1}{2}(1)(16 - 0.5\times 1\times g\sin\theta) - 1(g)(0.5\sin\theta)$	**A1**	**1.1**	Correct equation in θ only – note that $32 = 29.4\sin\theta + 20.48$ (oe) scores the first four marks
	$\theta = 23.1$	**A1**	**1.1**	**AG** allow awrt 23.1 (for reference: 23.068…) should be from $\sin\theta = \frac{96}{245}$ or 0.3918… - condone 23.1 being stated after a correct equation (as **AG must check this carefully**) – any wrong working seen scores **A0 – note that θ might be defined as the angle to the vertical – if $90 - \theta$ is then considered then allow for full marks**
		[5]		

11(c)	Vertical distance to fall is 1.55 or $1.75-0.5\sin 23.1$	**B1**	**3.1b**	Allow $\frac{1523}{980}$ or an answer in the interval [1.544, 1.554] – **3** sf (e.g. 1.54 **or** 1.55) or better
	Velocity when string breaks is 3.75 (m s^{-1})	**B1**	**1.1**	Allow for $v^2=\frac{352}{25}$ **or** $v=\frac{4\sqrt{22}}{5}$ **or** awrt 3.75 for v or a value in the interval [14.077, 14.085] for v^2 – **3** sf (e.g. 3.75) or better (allow un-simplified e.g. $v=\sqrt{10.24+g\sin 23.1}$ or $v=\sqrt{16-0.5\times g\sin 23.1}$)
	$\frac{1}{2}V^2=\frac{1}{2}\times 3.75^2+g(1.75-0.5\sin 23.1)$ or $V^2=(3.75\times\sin 23.1)^2+(3.75\times\cos 23.1)^2+2\times g\times 1.55$	**M1**	**3.4**	Conservation of Energy with correct number of terms but allow sign errors – with their 14.08 or 3.75 (but **M0** if using 3.2) – for h allow from $1.75-0.5\sin 23.1$ or $1.75-0.5\cos 23.1$ **only**. Their 3.75 must come from an equation with the correct number of relevant terms. If using $v^2=u^2+2as$ to find V, then must be using the equivalent of their 3.75 and not just a single component of their 3.75 (must also be using $a=\pm g$)
	$V=6.67$ (m s^{-1})	**A1**	**1.1**	If using exact values may see $V^2=\frac{2227}{50}$ - awrt 6.67 – **3** sf or better
		[4]		
	Alternative solution			
		M1		Conservation of Energy (loss of PE = gain in KE) – setting up an equation with the correct number of terms using the 1.75, 3.2 and the speed of P at A **only**
	$1\times g\times 1.75=\frac{1}{2}\times 1\times(v^2-3.2^2)$	**A1 A1**		**A1** for correct LHS, **A1** for correct RHS
	$v=6.67$ (m s^{-1})	**A1**		awrt 6.67 **– 3** sf or better

11(d)	$1.75 - 0.5\sin 23.1 = (3.75\cos 23.1)t + 0.5gt^2$	**M1***	**3.3**	For vertical motion – if correct expect to see $1.55... = 3.45t + 0.5gt^2$ - using **their** $3.75 \times \cos 23.1$ or their $3.75 \times \sin 23.1$ (from part **(c)**). Allow sign errors on RHS, but LHS **must be** $1.75 - 0.5\sin 23.1$ **only**. Must be using $a = \pm g$. Watch out for other complete methods that lead to the time of flight e.g. finding the two vertical components of velocity and applying $v = u + at$ with $a = g$ e.g. if correct expect to see $6.51 - 3.45 = gt$ or $6.50 - 3.45 = gt$ (oe)
	Time to A is 0.312 (s)	**A1**	**1.1**	awrt 0.312 or awrt 0.311 or allow 0.31 www (if using exact then answer is 0.3121…) – also allow correct un-simplified expression for t e.g. $\frac{6.51(\text{or } 6.50) - 3.45}{g}$ (but must be a correct expression for t and not just an equation containing t)
	Horizontal distance travelled = $0.31... \times (3.75\sin 23.1)$	**M1dep***	**3.4**	Use of $s = ut$ horizontally with their t – allow sin/cos mix but **must** be using the correct value of 3.75 now
	Distance = 0.459	**A1**	**1.1**	awrt 0.459 or 0.458 www (but not just 0.46) – so must have been using a correct t
	(Which is very close to) $0.5\cos 23.1 = 0.460$ (so A is almost directly below O)	**A1**	**3.5a**	Must **either** explicitly state that $0.5\cos 23.1 = 0.459…$ or 0.46 (or better) **or** show the difference between the two values is very close to zero (if either value is not explicitly stated) – as a minimum must show explicitly both values (but no further comment required) www (dependent on all previous marks)
		[5]		

Question	Answer	Marks	AO	Guidance
12(a)	Velocity perpendicular to XY does not change and is zero after (so therefore A must have been moving along XY before the collision)	B1 [1]	2.4	Accept 'perpendicular impulse is zero and A is moving to the right before collision' oe – as a minimum must refer to either the vertical component of velocity is zero or unchanged **or** that the perpendicular impulse is zero
12(b)		M1	3.3	CLM - correct number of terms but allow sign errors and sin/cos mix with the 60-degree angle, where a is the component of the velocity of A before collision, and b is the component of the velocity of B after collision – for b accept $v\cos\theta$ but no angle associated with a
	$3a + 5 = 5b$ or $3a + 5(2\cos 60) = 5b$	A1	1.1	
		M1	3.3	NEL; correct number of terms – allow sign errors and sin/cos mix with the 60-degree angle but e must be with the approach speed - for b accept $v\cos\theta$ but no angle associated with a
	$b = -0.8 + 0.8a$ or $b - 0 = -0.8(2\cos 60 - a)$	A1	1.1	Must be consistent with CLM
	Speed of A before is $9\ (\text{m s}^{-1})$	A1	1.1	Condone just leaving answer as $a = 9$
	$b = 6.4$	A1	2.1	Or $v\cos\theta = 6.4$ - this mark can be implied by a correct speed of B
	Speed of B after is $\sqrt{b^2 + (2\sin 60)^2} = 6.63\ (\text{m s}^{-1})$	A1 [7]	1.1	awrt 6.63 or allow 6.6 www

Question	Answer	Marks	AO	Guidance
12(c)	$\tan\theta = \frac{2\sin 60}{b}$	M1	3.1b	Their value of b from part **(a)** must be substituted **or** for $\sin\theta = \frac{2\sin 60}{6.63}$ with their 6.63 **or** $\cos\theta = \frac{b}{6.63}$ with their b **and** their 6.63 – allow $\tan\theta = \frac{b}{2\sin 60}$ with their b
	$\theta = 15.1$	A1	1.1	awrt 15.1 or 15 www – this mark can be implied by a correct final answer of 44.9
	Angle turned through is $44.9(^\circ)$	A1FT	3.2a	Follow through $60-\theta$ provided $60-\theta > 0$ (so θ must be less than 60 for this **FT** mark) and **M1** awarded – awrt 44.9 or allow 45 www
		[3]		

12(d)	Component of velocity perp to XY after collision is $e(2\sin 60)$	**B1**	**3.1b**	soi
	KE before collision is $\frac{1}{2}\times 5\times(6.4^2+(2\sin 60)^2)\left(=109.9\right)$ **or** speed component squared before collision is $6.4^2+(2\sin 60)^2$ **or** speed component squared after collision is $6.4^2+(2e\sin 60)^2$	**B1FT**	**1.1**	Follow through their value of b (the 6.4) from part **(b)** only
	$\frac{1}{2}\times 5\times(6.4^2+(e\times 2\sin 60)^2)=0.95\times\frac{1}{2}\times 5\times(6.4^2+(2\sin 60)^2)$	**M1**	**3.4**	Correct use of **either** KE after = 0.95(KE before) **or** KE before = 0.95(KE after), condone lack of $\frac{1}{2}\times 5$ on both sides (but **M0** if wrong mass used), allow their value of b (the 6.4) but everything else **must** be correct
	$e=0.517$	**A1** **[4]**	**1.1**	awrt 0.517 or allow 0.52 www

Question	Answer	Marks	AO	Guidance
13(a)	$T = 4g$	**B1***	**1.1**	Resolving vertically for P (soi e.g. in an **equation** for Q)
	$T\cos\alpha + R\sin\alpha = 2g$	**M1***	**3.3**	Attempt to resolve vertically for Q – correct number of **relevant** terms so must contain a component of T and R but allow sign errors and sin/cos mix, must be dimensionally consistent and using correct mass of 2 kg but allow T instead of $4g$
	$4g\cos\alpha + R\sin\alpha = 2g$	**A1**	**1.1**	Where R is the normal contact force between Q and the surface of the shell – must be using 4g for T now
	$T\sin\alpha - R\cos\alpha = 2(h\tan\alpha)(2.8)^2$	**M1***	**3.3**	Applying N2L radially for Q – correct number of **relevant** terms so must contain a component of T and R but allow sign errors and sin/cos mix on LHS, must be dimensionally consistent and using correct mass of 2 kg but allow T instead of $4g$ – must be using $a = r(2.8)^2$ with either $r = h\tan\alpha$ or $r = \dfrac{h}{\tan\alpha}$ **only** (may have sub. for R)
	$4g\sin\alpha - R\cos\alpha = 2(h\tan\alpha)(2.8)^2$	**A1**	**1.1**	oe e.g. $4g\sin\alpha - R\cos\alpha = 15.68h\tan\alpha$ – must be using 4g for T now – **note that substituting an incorrect expression for *R* can still imply this mark**
	$4g\sin\alpha - \cos\alpha\left(\dfrac{2g - 4g\cos\alpha}{\sin\alpha}\right) = 15.68h\tan\alpha$	**M1dep***	**3.4**	Eliminate R from the two equations to obtain an equation in h and α only
	$4\cos\alpha - 2\cos^2\alpha = 1.6h\sin^2\alpha$ $\Rightarrow 4h\sin^2\alpha + 5\cos^2\alpha = 10\cos\alpha$	**A1**	**2.1**	e.g. $k_1 = 4, k_2 = 5$ and $k_3 = 10$ (must be integers but accept multiples of these but must be in this form) – values of k do not need to be stated explicitly
		[7]		

	Alternative Solution – applying N2L parallel to the surface of the shell			
	$T = 4g$	**B1**		Resolving vertically for P (soi)
	Acceleration component parallel to the plane is $2r(2.8)^2 \sin\alpha$	**B1**		soi – allow any trigonometric expression containing h and α for r but not just r
	$T - 2g\cos\alpha = 2(h\tan\alpha)(2.8)^2 \sin\alpha$	**M1**		Applying N2L parallel to the slope for Q – correct number of relevant terms (allow sign errors and sin/cos mix on LHS), must be dimensionally consistent (so component of Q's mass but no component with T) and using correct mass of 2 kg but allow T instead of $4g$. Must be using $a = r(2.8)^2 \sin\alpha$ or $a = r(2.8)^2 \cos\alpha$ with either $r = h\tan\alpha$ or $r = \dfrac{h}{\tan\alpha}$ **only – if no component of acceleration used then M0**
	$4g - 2g\cos\alpha = 2(h\tan\alpha)(2.8)^2 \sin\alpha$	**A3**		Award **A2** for all terms correct but with sign errors only, and **A1** for sign errors only with $a = (h\tan\alpha)(2.8)^2 \cos\alpha$
	$4g\cos\alpha - 2g\cos^2\alpha = 15.68h\sin^2\alpha$ $\Rightarrow 4h\sin^2\alpha + 5\cos^2\alpha = 10\cos\alpha$	**A1**		e.g. $k_1 = 4, k_2 = 5$ and $k_3 = 10$ (must be integers but accept multiples of these but must be in this form) – values of k do not need to be stated explicitly
		[7]		

13(b)	$4g\cos\alpha = 2g$ **or** $4g\sin\alpha = 2(h\tan\alpha)(2.8)^2$	**M1***	**3.1b**	Setting $R = 0$ or $R > 0$ or $R \geqslant 0$ in either their $4g\cos\alpha + R\sin\alpha = 2g$ or their $4g\sin\alpha - R\cos\alpha = 2(h\tan\alpha)(2.8)^2$ equation to obtain an equation/inequality in α (and possibly h) **only** – **dependent on having scored the corresponding M mark in part (a) or full working in this part (e.g. if applying N2L parallel to the surface only in part (a))**
	e.g. $\cos\alpha = \frac{1}{2} \Rightarrow 4g \times \frac{\sqrt{3}}{2} = 2h \times \sqrt{3} \times 2.8^2$ or $\cos\alpha = \frac{1}{2} \Rightarrow 4h \times \frac{3}{4} + 5 \times \frac{1}{4} = 10 \times \frac{1}{2}$	**M1dep***	**2.1**	Substituting their $4g\cos\alpha = 2g$ into either their $4g\sin\alpha = 2(h\tan\alpha)(2.8)^2$ **or** their answer to part **(a)** oe correct method that leads to an equation/inequality in h **only - dependent on having scored the corresponding M mark(s) in part (a) or full working in this part**
	$h = \frac{5}{4}$	**A1** **[3]**	**2.2a**	If $h \leqslant \frac{5}{4}$ or $h < \frac{5}{4}$ then must explicitly state that the greatest value is $\frac{5}{4}$ www

APPENDIX

Exemplar responses for 4(b)

Response	Mark
The first three marks are for forming two equations that can be used to find both F_A and R_A - most candidates will resolve horizontally and vertically to the rod (see main scheme). However, they may resolve parallel and perpendicular to the rod or take moments again. There are two marks for the first equation (**M1 A1**) and one mark (**A1**) for the second. Please mark to the benefit of the candidate so one correct equation and one incorrect equation would score 2 out of 3. The same rule applies for the second **M** mark in that their equations must contain the required number of relevant terms (so if they take moments again about a different point and e.g. a force/distance is missing then **M0** for the second **M** mark). $M(\text{peg}): \left(\frac{1.5}{\sin 25} - 2\right) \times 3g\cos 25 + \frac{1.5}{\sin 25} \times F_A \sin 25 = \frac{1.5}{\sin 25} \times R_A \cos 25$ $M(\text{com}): \left(\frac{1.5}{\sin 25} - 2\right) \times R_P + 2 \times F_A \sin 25 = 2 \times R_A \cos 25$ $M(\text{B}): \left(4 - \frac{1.5}{\sin 25}\right) \times R_P + 4 \times R_A \cos 25 = 2 \times 3g\cos 25 + 4 \times F_A \sin 25$ R(parallel): $F_A \cos 25 + R_A \sin 25 = 3g \sin 25$ R(perpendicular): $R + R_A \cos 25 = F_A \sin 25 + 3g\cos 25$	

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