



Oxford Cambridge and RSA

## Practice Paper – Set 3

A Level Further Mathematics A

Y543/01 Mechanics

**MARK SCHEME**

**Duration:** 1 hour 30 minutes

**MAXIMUM MARK 75**

**FINAL**

**This document consists of 12 pages**

## Text Instructions

## 1. Annotations and abbreviations

Annotation in scoris	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
SC	Special case
^	Omission sign
MR	Misread
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 *
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 includes the instruction: In this question you must show detailed reasoning.

## 2. Subject-specific Marking Instructions for A Level Further Mathematics A

- a Annotations should be used whenever appropriate during your marking. The A, M and B annotations must be used on your standardisation scripts for responses that are not awarded either 0 or full marks. It is vital that you annotate standardisation scripts fully to show how the marks have been awarded. For subsequent marking you must make it clear how you have arrived at the mark you have awarded.
- 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 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**

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**

Mark for explaining a result or establishing a given result. 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. This rule should be applied to each case. When a value is not given in the paper accept any answer that agrees with the correct value to 2 s.f. Follow through should be used so that only one mark is lost for each distinct accuracy error, except for errors due to premature approximation which should be penalised only once in the examination. There is no penalty for using a wrong value for *g*. E marks will be lost except when results agree to the accuracy required in the question.
- g Rules for replaced work: if a candidate attempts a question more than once, and indicates which attempt he/she wishes to be marked, then examiners should do as the candidate requests; if there are two or more attempts at a question which have not been crossed out, examiners should mark what appears to be the last (complete) attempt and ignore the others. NB Follow these maths-specific instructions rather than those in the assessor handbook.
- 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 mark in the question. Marks designated as cao may be awarded as long as there are no other errors. E marks are lost unless, by chance, the given results are established by equivalent working. 'Fresh starts' will not affect an earlier decision about a misread. 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, of course, that there is nothing in the wording of the question specifying that analytical methods are required). 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	AOs	Guidance
1	(a)	$\text{KE} = \frac{1}{2} \times 2 \times \begin{pmatrix} -19.5 \\ -60 \end{pmatrix} \cdot \begin{pmatrix} -19.5 \\ -60 \end{pmatrix} = 19.5^2 + 60^2$ awrt 3980 J	M1  A1 [2]	1.1a  1.1	Using $\text{KE} = \frac{1}{2} m \mathbf{v} \cdot \mathbf{v}$ or $\frac{1}{2} m v^2$ and attempting to find dot product or magnitude
1	(b)	$\begin{pmatrix} 4t \\ -2 \end{pmatrix} = 2\mathbf{a} = 2 \frac{d\mathbf{v}}{dt}$ $\Rightarrow \mathbf{v} = \begin{pmatrix} t^2 \\ -t \end{pmatrix} + \mathbf{u}$ $t = 0 \Rightarrow \mathbf{u} = \begin{pmatrix} -19.5 \\ -60 \end{pmatrix} \text{ so } \mathbf{v} = \begin{pmatrix} t^2 - 19.5 \\ -t - 60 \end{pmatrix} \text{ oe}$ $P = \mathbf{F} \cdot \mathbf{v} = \begin{pmatrix} 4t \\ -2 \end{pmatrix} \cdot \begin{pmatrix} t^2 - 19.5 \\ -t - 60 \end{pmatrix} = 4t^3 - 76t + 120$ $4t^3 - 76t + 120 = 0$ $t = 2, 3$	M1  M1  A1  M1  A1 A1 [6]	1.1  1.1  1.1  1.1  1.1 2.2a	Using $\mathbf{F} = m\mathbf{a}$ with $\mathbf{a} = \frac{d\mathbf{v}}{dt}$ so  Integrating to find $\mathbf{v}$ ( $\mathbf{u}$ may be missing or may look like a scalar at this stage)  Using $P = \mathbf{F} \cdot \mathbf{v}$ and attempt at dot product  <b>BC</b> If $t = -5$ included then <b>A0</b>

Question		Answer	Marks	AOs	Guidance
2	(a)	$15\,000 \times 6 = \frac{1}{2} \times 800v^2$ $v = \sqrt{225} = 15 \text{ m s}^{-1}$	M1  A1 [2]	1.1a  1.1	Finding energy input using $W = Pt$ and equating to KE gained  Or $\frac{15\,000}{v} = 800 \frac{dv}{dt}$ $\Rightarrow \frac{75}{2} \int_0^6 dt = \int_0^v 2v \, dv$ oe
2	(b)	Considering forces along the road: $800g \sin \theta + 150 = D$  $15\,000 = Dv$  $v = \frac{15\,000}{800g \times \frac{1}{20} + 150} = \text{awrt } 27.7 \text{ m s}^{-1}$	M1  M1  A1 [3]	1.1a  1.1  1.1	Where $D$ is the driving force  Use of $P = Fv$  $27.675276\dots$  Or $W = 800gd \sin \theta + 150d$ , where $d$ is distance travelled ... ... in time $t$ and $W = 15\,000t$ and $v = \frac{d}{t}$
2	(c)	$D = \frac{15000}{30} \quad (= 500)$ $\frac{15\,000}{30} = R_{\text{total}}$ $R_c = \frac{3}{4} \times 500 = 375 \text{ N}$ Car: $500 = T + 375 \Rightarrow T = 125 \text{ N}$	M1  M1  A1  A1 [4]	1.1a  2.2a  1.1  1.1	Driving force ...  ... equals total resistance  Or Trailer: $T = R_T = \frac{1}{4} \times 500 = 125 \text{ N}$

Question	Answer	Marks	AOs	Guidance
3	<p>A colliding with B: <math>2 \times 5u = 2v_A + 3v_B</math></p> $\frac{v_B - v_A}{5u} = 1$ <p><math>v_A = -u</math> and <math>v_B = 4u</math></p> <p>B colliding with C: <math>3 \times 4u = 3V_B + 5V_C</math></p> $\frac{V_C - V_B}{4u} = e$ $V_B = \frac{u(3 - 5e)}{2}$ $e \leq 1 \Rightarrow V_B \geq \frac{u(3 - 5)}{2} = -u$ <p>So A and B are both travelling in the negative direction, but <math> v_A  \geq  v_B </math> hence B and A do not collide again, ie there are only two collisions (AG)</p>	<p>M1</p> <p>M1</p> <p>A1</p> <p>M1</p> <p>M1</p> <p>A1</p> <p>M1</p> <p>E1</p> <p>[8]</p>	<p>1.1</p> <p>1.1</p> <p>1.1</p> <p>1.1</p> <p>1.1</p> <p>1.1</p> <p>2.1</p> <p>2.2a</p>	<p>Conservation of momentum</p> <p>NEL</p> <p>Both</p> <p>Conservation of momentum</p> <p>NEL</p> <p>Correct <math>V_B</math></p> <p>oe; eg stating that the greatest leftwards speed of B occurs when <math>e = 1</math> and evaluating this</p> <p>Conclusion correctly drawn</p> <p><math>V_C = \frac{3u(1+e)}{2}</math>, but this need not be stated; ignore any wrong value seen, provided not used further</p> <p>Or could see eg assumption <math>V_B &lt; v_A</math> leading to <math>e &gt; 1</math> stated as a contradiction</p> <p>Allow statement such as 'B is not catching up with A' in place of a formal inequality, provided correct working is seen</p>

Question		Answer	Marks	AOs	Guidance
4	(a)	$F = k\sqrt{9+1.25^2} = 13$ $k = 4$ $4\sqrt{9+v^2} = 8 \frac{dv}{dt} \Rightarrow \frac{1}{\sqrt{9+v^2}} \frac{dv}{dt} = \frac{1}{2}$ (AG)	<b>M1</b> <b>A1</b> <b>A1</b> <b>[3]</b>	<b>3.3</b> <b>1.1</b> <b>3.3</b>	Substituting $v = 1.25$ and $F = 13$  Clear use of $F = ma$ leading to AG
4	(b)	$\int \frac{1}{\sqrt{9+v^2}} dv = \frac{1}{2}t + c$ $\sinh^{-1}\left(\frac{v}{3}\right) = \frac{1}{2}t + c$ $c = 0$ $v = 3\sinh\left(\frac{1}{2}t\right)$	<b>M1</b> <b>M1</b> <b>B1</b> <b>A1</b> <b>[4]</b>	<b>3.4</b> <b>3.4</b> <b>1.1</b> <b>3.4</b>	Separating the variables and correctly integrating to obtain $bt$  Integrating other side to obtain $p \sinh^{-1} qv$  Substituting $t = 0, v = 0$ into a solution of the DE to obtain $c$  Or using 0 as limits on integrals
4	(c)	$\frac{dx}{dt} = 3\sinh\left(\frac{1}{2}t\right) \Rightarrow x = C + 6\cosh\left(\frac{1}{2}t\right)$ $t = 0, x = 0 \Rightarrow C = -6 \Rightarrow x = 6\left(\cosh\left(\frac{1}{2}t\right) - 1\right)$ oe	<b>M1</b> <b>A1</b> <b>[2]</b>	<b>3.4</b> <b>2.2a</b>	Replacing $v$ with $\frac{dx}{dt}$ and integrating to obtain $r \cosh st$  Condone omission of $C$ (or use of 'c' again)
5	(a)	$\frac{1}{2}m \times 3.5^2 = \frac{1}{2}mv^2 + mg \times 0.8(1 - \cos \frac{1}{3}\pi)$ $v^2 = 3.5^2 - 0.8g = 4.41$ $T - 1.2g \cos \frac{1}{3}\pi = \frac{1.2v^2}{0.8}$ So tension when string breaks is awrt 12.5 N	<b>M1</b> <b>A1</b> <b>M1</b> <b>A1</b> <b>[4]</b>	<b>3.1b</b> <b>1.1</b> <b>3.1b</b> <b>3.2a</b>	Conservation of energy (could be general angle for RHS) Or $v = 2.1$  Resolving weight and use of NII with correct centripetal acceleration



Question		Answer	Marks	AOs	Guidance	
5	(b)	$v_y = 2.1 \sin \frac{1}{3} \pi$ upwards	M1	3.1b	Direction can be implied by eg use of $-9.8$	
		$P$ starts freefall $1.5 + 0.8(1 - \cos \frac{1}{3} \pi)$ above plane	B1	3.1b	(= 1.9)	
		$-(1.5 + 0.8(1 - \cos \frac{1}{3} \pi)) = (2.1 \sin \frac{1}{3} \pi)t - \frac{1}{2}gt^2$	M1	1.1	Setting up 3 term quadratic equation in $t$ with adjustment to $\pm 1.5$ as displacement	
		$-1.9 = (1.05\sqrt{3})t - 4.9t^2$ or $4.9t^2 - 1.8186K t - 1.9 = 0$	A1	1.1	Correct equation soi	
		$t = \text{awrt } 0.835$	A1	1.1	BC	
		Horizontal distance in freefall is $2.1 \cos \frac{1}{3} \pi \times 0.835 \dots$	M1	1.1	0.877...	
			$0.8 \sin \frac{1}{3} \pi + 2.1 \cos \frac{1}{3} \pi \times 0.835 \dots = \text{awrt } 1.57 \text{ m}$	A1	2.2a	horizontal distance while attached plus horizontal distance in freefall.
		<b>Alternative solution</b>				
			Projection velocity is $2.1 \text{ m s}^{-1}$ at $\frac{1}{3} \pi$ above horizontal	B1ft		soi; ft their 2.1
			$P$ starts freefall $1.5 + 0.8(1 - \cos \frac{1}{3} \pi)$ above plane	B1		(= 1.9)
			Equation of trajectory: $y = x \tan \frac{1}{3} \pi - \frac{gx^2}{2 \times 2.1^2 \cos^2(\frac{1}{3} \pi)}$	M1		Or suitably adjusted if not using $P$ 's position when string breaks as the origin
			$-1.9 = x\sqrt{3} - \frac{40}{9}x^2$ or $4.444K x^2 - 1.732K x - 1.9 = 0$	A1ft		Correct equation (with their 2.1) soi
	$x = \text{awrt } 0.877$	M1		oe: formulation of explicit quadratic equation in $x$		
	$0.8 \sin \frac{1}{3} \pi + 0.877 \dots = \text{awrt } 1.57 \text{ m}$	A1		BC		
		[7]				

Question		Answer	Marks	AOs	Guidance	
6	(a)	$[F] = [ma] = \text{MLT}^{-2}$ $[P] = \frac{[F]}{[A]} = \text{MLT}^{-2}\text{L}^{-2} = \text{ML}^{-1}\text{T}^{-2}$ $[R] = [F][d]$ $[R] = \text{MLT}^{-2}\text{L} = \text{ML}^2\text{T}^{-2}$	<b>M1</b> <b>A1</b> <b>M1</b> <b>A1</b> <b>[4]</b>	<b>1.2</b> <b>2.2a</b> <b>3.1b</b> <b>3.2a</b>	Determining dimensions of energy	
6	(b)	$(\text{ML}^{-1}\text{T}^{-2})^\alpha \text{L}^{3\beta} = \text{ML}^2\text{T}^{-2}$ $\text{M}^\alpha = \text{M} \Rightarrow \alpha = 1$ (AG) $\text{L}: -\alpha + 3\beta = 2 \Rightarrow \beta = 1$ (AG)	<b>M1</b> <b>A1</b> <b>A1</b> <b>[3]</b>	<b>3.3</b> <b>3.4</b> <b>1.1</b>	Using their dimensions or similarly with T  $n$ and $\theta$ dimensionless	
6	(c)	$P = \frac{5 \times 8.31 \times 300}{0.03}$ $415\,500 \text{ N m}^{-2}$	<b>M1</b> <b>A1</b> <b>[2]</b>	<b>3.4</b> <b>1.1</b>	Correctly substituting values	With their $\alpha$ and $\beta$
6	(d)	$[b] = \text{L}^3$ $[a] = \text{ML}^{-1}\text{T}^{-2}(\text{L}^3)^2$ $[a] = \text{ML}^5\text{T}^{-2}$	<b>B1</b> <b>M1</b> <b>A1</b> <b>[3]</b>	<b>2.2a</b> <b>2.2a</b> <b>1.1</b>	Using equality of $[a/V^2]$ and $[P]$	With $n$ dimensionless
6	(e)	$P + \frac{0.14 \times 5^2}{0.03^2} = \frac{5 \times 8.31 \times 300}{0.03 - 5 \times 3.2 \times 10^{-5}}$ awrt $414\,000 \text{ N m}^{-2}$	<b>M1</b> <b>A1</b> <b>[2]</b>	<b>3.4</b> <b>1.1</b>	Correctly substituting values	With their $\alpha$ and $\beta$
6	(f)	$P = \frac{5 \times 8.31 \times 300}{1.5 \times 10^{-4} - 5 \times 3.2 \times 10^{-5}} - \frac{0.14 \times 5^2}{(1.5 \times 10^{-4})^2} \approx -1.4 \times 10^9$ A negative value is not a valid value for pressure... ...and so the model is not valid for these values	<b>B1</b> <b>E1</b> <b>E1</b> <b>[3]</b>	<b>3.4</b> <b>3.5b</b> <b>2.2a</b>	Ignore units	OR from $V - nb < 0$ , so since $R$ , $\theta$ , $n$ and $V$ are all positive $P < 0$

Question		Answer	Marks	AOs	Guidance
7	(a)	Use of $\bar{x} = \frac{\sum mx}{\sum m}$ or $\bar{y} = \frac{\sum my}{\sum m}$ $\bar{x} = \frac{2 \times 0 + 3 \times 0.6 + 5 \times 0.4}{2 + 3 + 5} = \frac{3.8}{10} = 0.38 \quad (\text{AG})$ $\bar{y} = \frac{2 \times 0 + 3 \times 0 + 5 \times 0.2}{2 + 3 + 5} = \frac{1}{10} = 0.1$	M1 A1 A1 [3]	1.2 3.3 3.3	Values must be substituted Intermediate step must be seen
7	(b)	$G$ is not on the frame so the weight would have an unbalanced moment about the support point	E1 [1]	2.4	
7	(c)	Moments about $B$ : $0.6T = 10g \times 0.1$ $T = \frac{g(0.8 - l)}{l}$ Eliminate $T$ : $\frac{5g}{3} = \frac{g(0.8 - l)}{l} \Rightarrow 8l = 2.4 \Rightarrow l = 0.3 \quad (\text{AG})$	M1 M1 A1 [3]	3.4 3.4 1.1	Each term must be of the form $F \times d$ Correct form for Hooke's law Intermediate working must be seen
7	(d)	Any two resolving equations oe, eg: (vertically): $R \cos \theta + F \sin \theta = 10g$ (horizontally): $R \sin \theta = F \cos \theta + T$ (parallel to plane): $F + T \cos \theta = 10g \sin \theta$ (perpendicular to plane): $R = T \sin \theta + 10g \cos \theta$  Use $T = \frac{5}{3}g$ , $\sin \theta = \frac{3}{5}$ , $\cos \theta = \frac{4}{5}$ to derive equations $4R + 3F = 50g$ and $9R = 12F + 25g$ oe $R = 9g$ and $F = \frac{14}{3}g$ $F \leq \mu R \Rightarrow \frac{14}{3}g \leq \mu \times 9g$ $\therefore \mu \geq \frac{14g}{3 \times 9g} = \frac{14}{27} \quad (\text{AG})$	M1 M1 M1 A1 M1 A1 [6]	3.4 3.4 1.1a 1.1 3.4 1.1	Or taking moments eg about the point where the string is attached to the plane ( $1 \times N = (0.8 + 0.1) \times 10g$ ) or the point where the lines of action of $R$ and the weight intersect: $\frac{0.1}{\sin \theta} \times F = \left(0.6 - \frac{0.1}{\tan \theta}\right) \times T$ $R$ is the normal contact force, $F$ is the frictional force (up the slope) Forming equations that lead to numerical values for $F$ and $R$ Both $F \leq \mu R$ with values substituted in Intermediate working must be seen

