GCE

Further Mathematics A

Y543/01: Mechanics

Advanced GCE

Mark Scheme for June 2019

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.

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.

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 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 **3 s.f.** unless the question specifically asks for another level of accuracy.
  NB for Specification B (MEI) the rubric is not specific about the level of accuracy required, so this statement reads “2 s.f”.

Follow through should be used so that only one mark is lost for each distinct accuracy error.

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)		(G lies on the axis of) symmetry (of R)	B1 [1]	1.2	Accept 'symmetrical'	Not 'distributed uniformly around the axis'
1	(b)		$\int_1^4 (2x^3 - 15x^2 + 36x - 20)\,dx = \frac{45}{2}$	B1	1.1a	**BC** With or without π soi	If treats as lamina award 0
			$\int_1^4 (2x^4 - 15x^3 + 36x^2 - 20x)\,dx = \frac{1179}{20}$	B1	1.1	**BC** With or without π soi	
			$\bar{x} = \dfrac{\int_1^4 (2x^4 - 15x^3 + 36x^2 - 20x)\,dx}{\int_1^4 (2x^3 - 15x^2 + 36x - 20)\,dx}$	M1	1.1	Either no π or seen on both top and bottom	
			$\bar{x} = \dfrac{\frac{1179}{20}}{\frac{45}{2}} = \frac{131}{50}$ or 2.62	A1 [4]	1.1		
1	(c)		$PC = \sqrt{12} = 2\sqrt{3} = 3.46\ldots$	B1	1.1	soi	C is the centre of the larger circle Can use a clearly stated value of PC
			$\tan\theta = \dfrac{"\sqrt{12}"}{4 - "2.62"} = (2.51\ldots)$	M1	1.1	Allow $\dfrac{4 - 2.62}{\sqrt{12}}$ $(= 0.398\ldots)$	1< "2.62" <4
			1.19 rad or 68.3°	A1 [3]	1.1		

Question			Answer	Marks	AOs	Guidance	
2	(a)		$[a] = LT^{-2}$	B1	3.3		
			$[h] = L$ and $[m] = M$ and $[v] = LT^{-1}$	B1	1.2		
			M: $0 = 1 + \alpha$ so $\alpha = -1$	B1	3.3		
			L: $1 = 1 + \beta + \gamma$	M1	1.1		
			T: $-2 = -1 - \beta$	M1	3.4		
			$\beta = 1$ and $\gamma = -1$	A1 [6]	1.1	www	
2	(b)		$(9.11 \times 10^{-31})^{-1}$ or $(1.67 \times 10^{-27})^{-1}$ oe	M1	3.4	Using $a \propto \frac{1}{m}$	
			$(9.11 \times 10^{-31})^{-1} : (1.67 \times 10^{-27})^{-1}$	M1	2.2a	Division of values or forming a ratio	Could be either way round
			$1.67 \times 10^{-27} : 9.11 \times 10^{-31}$ or awrt 1830 (:1)	A1 [3]	1.1	Accept answers in words (eg the acceleration of the electron is 1830 times the acceleration of the proton)	Reciprocals not acceptable in final answer
2	(c)		Because N is a dimensionless quantity	E1 [1]	3.5b	Must see 'dimensionless' or 'no dimensions'	

Question			Answer	Marks	AOs	Guidance	
3	(a)		$\mathbf{x}(5)=5\begin{pmatrix}2\\-5\end{pmatrix}+\frac{1}{2}\times5^2\times\begin{pmatrix}1\\2\end{pmatrix}$	M1	3.1b	soi	Award SC2 for using **v** = **u** + **a**t to find **v** and then KE Must be complete and correct if not SC0
			$\mathbf{x}(5)=\begin{pmatrix}22.5\\0\end{pmatrix}$	A1	1.1		
			$\mathbf{v.v}=\begin{pmatrix}2\\-5\end{pmatrix}.\begin{pmatrix}2\\-5\end{pmatrix}+2\begin{pmatrix}1\\2\end{pmatrix}.\begin{pmatrix}22.5\\0\end{pmatrix}$	M1	3.1b		
			$\mathbf{v.v}=4+25+45=74$	M1	1.1		
			$\text{KE}=\frac{1}{2}\times m\times74=37m$	A1	2.2a	**AG www**	
			Alternate method				
			Substitute $\mathbf{x}=\mathbf{u}t+\frac{1}{2}\mathbf{a}t^2$ into $\mathbf{v.v}=\mathbf{u.u}+2\mathbf{a.x}$	M1		or $\mathbf{v.v}$ with $\mathbf{v}=\mathbf{u}+\mathbf{a}t$	
			to get $\mathbf{v.v}=\mathbf{u.u}+2\mathbf{a.u}t+\mathbf{a.a}t^2$	A1			
			$\mathbf{v.v}=\begin{pmatrix}2\\-5\end{pmatrix}.\begin{pmatrix}2\\-5\end{pmatrix}+2\times5\begin{pmatrix}1\\2\end{pmatrix}.\begin{pmatrix}2\\-5\end{pmatrix}+25\begin{pmatrix}1\\2\end{pmatrix}.\begin{pmatrix}1\\2\end{pmatrix}$	M1			
			$\mathbf{v.v}=4+25+10(2-10)+25(1+4)=74$	M1			
			$\text{KE}=\frac{1}{2}\times m\times74=37m$	A1		**AG**	
				[5]			
3	(b)	(i)	$P=m\begin{pmatrix}1\\2\end{pmatrix}.\begin{pmatrix}2\\-5\end{pmatrix}$ or equiv vector form	M1	2.2a		
			$P=m(2-10)=-8m$	A1 **[2]**	1.1	**AG www**	Must see 2-10 or 2m – 10m
3	(b)	(ii)	*E.g.* Q is slowing down	B1 **[1]**	2.2a	or Kinetic Energy is decreasing	

Question			Answer	Marks	AOs	Guidance	
3	(c)	(i)	$\mathbf{v}=\begin{pmatrix}2\\-5\end{pmatrix}+\begin{pmatrix}1\\2\end{pmatrix}t$ or $\mathbf{v}=\begin{pmatrix}2+t\\-5+2t\end{pmatrix}$	B1	1.1	$\mathbf{v}=\mathbf{u}+\mathbf{a}t$ soi	May be derived from integrating **a**
			$m\mathbf{a}.\mathbf{v}=m\begin{pmatrix}1\\2\end{pmatrix}.\begin{pmatrix}2+t\\-5+2t\end{pmatrix}=0\Rightarrow 2+t+2(-5+2t)=0$	M1	2.2a	Allow missing m; must have = 0	Must be equation in terms of t. Condone one slip
			Time taken is 1.6 s	A1	1.1	www	
			Alternate method				
			$\mathbf{v}=\begin{pmatrix}2\\-5\end{pmatrix}+\begin{pmatrix}1\\2\end{pmatrix}t$ or $\mathbf{v}=\begin{pmatrix}2+t\\-5+2t\end{pmatrix}$	B1		$\mathbf{v}=\mathbf{u}+\mathbf{a}t$ soi	
			$\frac{1}{2}m\mathbf{v}.\mathbf{v}=\frac{1}{2}m(5t^2-16t+29)\Rightarrow 10t-16=0$	M1		Find minimum	Allow missing $\frac{1}{2}m$
			Time taken is 1.6 s	A1		www	
				[3]			
3	(c)	(ii)	$\frac{1}{2}m\mathbf{v}.\mathbf{v}=\frac{1}{2}m\begin{pmatrix}2+1.6\\-5+2\times1.6\end{pmatrix}.\begin{pmatrix}2+1.6\\-5+2\times1.6\end{pmatrix}$	M1	2.2a	With their 1.6	
			$\frac{81}{10}m$ J or 8.1m J	A1	1.1		
				[2]			

Question			Answer	Marks	AOs	Guidance	
4	(a)		$T=\frac{32\times1.5}{2}=24$	M1 A1 [2]	3.4 1.1	Use $T=\frac{\lambda x}{l}$ Obtain 24	
	(b)		$\theta = 36.9\ (or\ 53.1)$	B1	2.1	Or correct trig ratio given Candidate may give θ between horizontal so cos and sin values will be the other way round	θ is the angle between the string and the downwards vertical
			$r(= 3.5\sin\theta) = 2.1$	B1	3.4	soi	
						m, g, r and/or T may appear as values throughout	
			$T\cos\theta + R\sin\theta = mg$	*M1	3.3	Resolving tension and contact force vertically and balancing with weight	Must have 3 terms; allow sign/trig errors
			$T\sin\theta - R\cos\theta = ma$	*M1	1.1	NII with 3 terms, components of tension and contact force	Must have 3 terms; allow sign/trig errors
			$a=\frac{v^2}{r}$	B1	1.1	Use $a=\frac{v^2}{r}$ to eliminate a and introduce v	Could use $a = r\omega^2$ but must see $v = r\omega$ as well
			$25T = 20mg + 15\frac{mv^2}{r}$	dep *M1	1.1	Solve simultaneously to eliminate R	May find $R=\frac{53}{6}$ and sub in
			$v = 2.48$	A1	1.1	Substitute values and find v	Or $\frac{\sqrt{154}}{5}$

Question			Answer	Marks	AOs	Guidance	
			Alternate method				
			$\theta = 36.9\ (or\ 53.1)$	**B1**		Or correct trig ratio given Candidate may give θ between horizontal so cos and sin values will be the other way round	θ is the angle between the string and the downwards vertical
			$r(= 3.5\sin\theta) = 2.1$	**B1**		soi	
						m, g, r and/or T may appear as values throughout	
			Acc component parallel to string is $a\sin\theta$	**M1**		Attempt to resolve acceleration	
			$T - mg\cos\theta = ma\sin\theta$	**M1**		NII with 3 terms, parallel to string	Must have 3 terms; allow sign/trig errors
			$= m\dfrac{v^2}{r}\sin\theta$	**M1**		Use $a = \dfrac{v^2}{r}$ to eliminate a and introduce v	
			$v^2 = \dfrac{r(T - mg\cos\theta)}{m\sin\theta}$	**M1**		Rearrange to make v^2 the subject or solve for v	
			$v = 2.48$	**A1**			
				[7]			

Question			Answer	Marks	AOs	Guidance	
5	(a)		$\lvert R\rvert = k\lvert v\rvert \Rightarrow 2 = 5k \Rightarrow k = 0.4$	M1	3.3		
			$F = ma \Rightarrow f - 0.4v = 4.5\frac{dv}{dt} \Rightarrow \frac{dv}{dt} = \frac{10f - 4v}{45}$	A1	3.3	AG	Must be clear equation has come from NII
				[2]			
5	(b)	(i)	$\int \frac{1}{10f - 4v}\,dv = \int \frac{1}{45}\,dt$ oe	B1	1.1	Correctly separating variables	Condone missing integral signs
			$-\frac{1}{4}\ln(10f - 4v) = \frac{t}{45} + c$	M1	1.1	Attempt to integrate – must be in the form $k\ln(a + bv) = pt(+c)$	
			$10f - 4v = Ae^{-\frac{4}{45}t}$	M1	1.1	Exponentiating correctly with a use of law indices/logs soi; allow disappearing mod signs	Or $-\frac{1}{4}\ln(10f - 4u) = c$ ie substituting $t = 0$ and $v = u$ into their integrated equation (perhaps manipulated) to find c
			$10f - 4u = A$	M1	3.4	Substituting $t = 0$ and $v = u$ into their integrated equation (perhaps manipulated) to find A	$\frac{10f - 4v}{10f - 4u} = e^{-\frac{4}{45}t}$ ie exponentiating correctly with a use of a law of indices/logs soi
			$4v = 10f - Ae^{-\frac{4}{45}t} \Rightarrow v = \frac{1}{2}\left(5f - (5f - 2u)e^{-\frac{4}{45}t}\right)$	A1	1.1	AG www	
				[5]			

			Alternate Method				

Question			Answer	Marks	AOs	Guidance	
			$IF = \mathrm{e}^{\int \frac{4}{45}\mathrm{d}t} = \mathrm{e}^{\frac{4}{45}t}$	B1		Must include e^{kt}	
			$\frac{\mathrm{d}}{\mathrm{d}t}\left(v\mathrm{e}^{\frac{4}{45}t}\right) = \frac{2}{9}f\mathrm{e}^{\frac{4}{45}t}$ **oe**	M1			
			$v\mathrm{e}^{\frac{4}{45}t} = \frac{5}{2}f\mathrm{e}^{\frac{4}{45}t} + c$	M1			
			$c = u - \frac{5}{2}f$	M1			
			$v = \frac{5}{2}f + \left(u - \frac{5}{2}f\mathrm{e}^{\frac{-4}{45}t}\right) \rightarrow$ $v = \frac{1}{2}(5f - (5f - 2u)\mathrm{e}^{\frac{-4}{45}t})$	A1			
				[5]			

Question			Answer	Marks	AOs	Guidance	
5	(b)	(ii)	$u < 2.5f \Rightarrow$ v increases (from u) and approaches 2.5f as $t \to \infty$	B1	3.4	Allow the idea that $v = 2.5f$ for large t, and allow technically inaccurate statements (eg "v speeds up") provided that intent is clear	SC: If B0B1B0 or B0B0B0 awarded. If mentions v approaches 2.5f for cases 1 **and** 3 award B1 or if mentions v increases in case 1 **and** v decreases in case 3 award B1
			$u = 2.5f \Rightarrow v = 2.5f$, constant	B1	3.4		
			$u > 2.5f \Rightarrow$ v decreases (from u) and approaches 2.5f as $t \to \infty$	B1 **[3]**	3.4	See above	
5	(c)		$\frac{dx}{dt} = \frac{1}{2}\left(5 - e^{-\frac{4}{45}t}\right)f$ oe	B1	1.1		
			$x = 2.5ft + \frac{45}{8}fe^{-\frac{4}{45}t} + c'$	*M1	3.4	Could be in a definite integral	
			$\Rightarrow c' = -\frac{45}{8}f$ and use of $t = 9$ to find x	Dep* M1	1.1	Substituting $t = 0$, $x = 0$ to obtain c', or $x = \left[2.5ft + \frac{45}{8}fe^{-\frac{4}{45}t}\right]_0^9$ with correct use of limits	
			$x = \frac{45}{8}\left(3 + e^{-0.8}\right)f$	A1 **[4]**	1.1		

Question			Answer	Marks	AOs	Guidance	
6	(a)		$\cos\theta = \frac{1}{2}$ or $\sin\theta = \frac{\sqrt{3}}{2}$	B1	3.1b	Must be clear where it comes from ie. Shown in diagram or clear use of distances. May be other way round	θ is the angle between the string and the direction of *AB* when the string initially becomes taut
			$v\sin\theta = (1+m)V$	M1	3.1b	Conservation of momentum in direction of string	
			$V = \frac{\sqrt{3}v}{2(1+m)}$	A1	3.1b	Working must be seen	
			$I = mV$ or $I = \pm(V - v\sin\theta)$ $V = \frac{v\times\frac{1}{2}\sqrt{3}}{1+m} \Rightarrow I = \frac{\sqrt{3}mv}{2(1+m)}$	A1	2.2a	**AG** Justification of using Impulse = change in momentum	
				[4]			
6	(b)		$\text{KE} = \frac{1}{2}\left(V^2 + (v\cos\theta)^2\right)$ soi	M1	3.1b	Transverse component unchanged and using their longitudinal component	Condone consideration of speed squared or inclusion of m in KE
			$\text{KE} = \frac{1}{2}\left(\left(\frac{\sqrt{3}v}{2(1+m)}\right)^2 + \left(v\times\frac{1}{2}\right)^2\right)$	M1	1.1	Substituting in for *V* and cosθ (could just be in speed equation)	
			$\text{KE} = \frac{v^2(4+2m+m^2)}{8(1+m)^2}$	A1	1.1	Or any equivalent single algebraic fraction	
				[3]			
6	(c)		$V = \frac{\sqrt{3}v}{2(1+m)} \to 0$ as $m \to \infty$	B1	3.2a	If m is very large then *A* is approximately stationary or *B* has only its transverse velocity of $\frac{1}{2}v$ after the string becomes taut	
			B moves (approximately) in a circle around *A*	B1	2.2b		
				[2]			

Question			Answer	Marks	AOs	Guidance	
7	(a)		$\frac{1}{2}mv^2 + m\gamma r\cos\theta = m\gamma r\cos\alpha$ oe	M1 A1	3.3 1.1	Conservation of energy	θ is the angle between *OP* and the upward vertical
			$v^2 + 2\gamma r\cos\theta = \frac{3}{2}\gamma r$				
			$m\gamma\cos\theta \quad (-C) = ma$	B1	1.1	NII for *P* at point where it is about to lose contact with surface.	Could see contact force, *C*, later set to 0
			$a = \frac{v^2}{r}$	B1	1.1	soi	
			$\cos\theta = \frac{a}{\gamma} = \frac{v^2}{\gamma r}$	M1	2.2a	Use previous two results to relate *v* and cos θ	
			$v^2 = \frac{1}{2}\gamma r$	A1	2.2a	for *v* or v^2 or $\cos\theta = \frac{1}{2}$	
			$r\cos\theta = \left(\sqrt{\frac{1}{2}\gamma r}\sin\theta\right)t + \frac{1}{2}\gamma t^2$	M1	3.4	Use of $s = ut + \frac{1}{2}at^2$ using their vertical component of v as u where v has come from consideration of theta	Or use of trajectory eqn: $y = x\tan\theta + \frac{\gamma x^2}{2v^2\cos^2\theta}$ with $y = r\cos\theta$ and $v^2 = \frac{1}{2}\gamma r$
			$t^2 + \sqrt{\frac{3r}{2\gamma}}t - \frac{r}{\gamma} = 0$	*M1	1.1	Reduction to 3 term quadratic with numerical values for trig ratios	$8x^2 + 2\sqrt{3}rx - r^2 = 0$
			$t = \frac{1}{4}\sqrt{\frac{r}{\gamma}}\left(\sqrt{22} - \sqrt{6}\right)$	Dep* M1	1.1	Solve for *t* (**BC**)	$x = \frac{\sqrt{11} - \sqrt{3}}{8}r$
			$OF = r\sin\theta + \sqrt{\frac{1}{2}\gamma r}\cos\theta \times \frac{1}{4}\sqrt{\frac{r}{\gamma}}\left(\sqrt{22} - \sqrt{6}\right)$	Dep* M1	3.4	Find *OF*	$r\sin\theta + \frac{\sqrt{11} - \sqrt{3}}{8}r$
			$OF = \frac{r}{8}\left(\sqrt{11} + 3\sqrt{3}\right)$ oe	A1	1.1		
				[11]			

Question			Answer	Marks	AOs	Guidance	
7	(b)		Unchanged since *OF* does not depend on γ	**E1** **[1]**	**3.5a**		

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The Triangle Building
Shaftesbury Road
Cambridge
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