GCE

Mathematics B MEI

H640/01: Pure Mathematics and Mechanics

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.
BP	Blank Page
Seen	
Highlighting	

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.

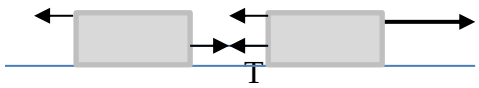
g. Rules for replaced work and multiple attempts:
- If one attempt is clearly indicated as the one to mark, or only one is left uncrossed out, then mark that attempt and ignore the others.
- If more than one attempt is left not crossed out, then mark the last attempt unless it only repeats part of the 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.

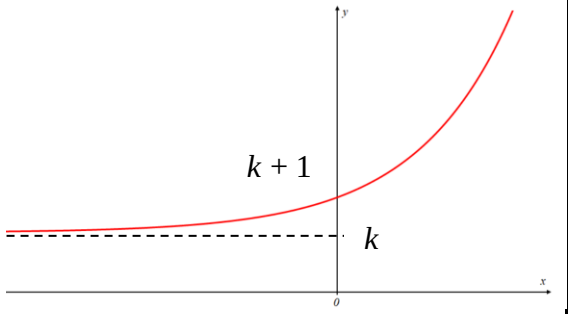
j. If in any case the scheme operates with considerable unfairness consult your Team Leader.

Question			Answer	Marks	AO	Guidance
1			When $x = 0$ $1+0^2 = 1$ and $(1+0)^2 = 1$ Values are equal, which contradicts the statement $1+x^2 < (1+x)^2$ for all values of x [So the statement is false]	**M1** **A1** **[2]**	**2.1** **2.1**	Using a negative value or zero Must see an explicit comparison between correct values (could be in words or symbols)

Question			Answer	Marks	AO	Guidance
2	(a)		300N 800N 6000N  	**B1**	**1.1**	Driving force and common tension correct and labelled. Allow T_1 and T_2 if later seen equated. Ignore any vertical forces shown. Also allow for common thrust.
				B1	**1.1**	Both resistances correct and labelled and no extra horizontal forces
				[2]		
2	(b)		N2L for system $6000-800-300=1800a$	**M1**	**1.1a**	Attempt to find resultant horizontal force. All forces included and no extras Allow sign errors.
				M1	**1.1a**	Attempts N2L equation with their total mass and their resultant. Do not allow for weight used instead of mass.
			$a=2.72\,\text{m s}^{-2}$ (to 3 s.f.)	**A1**	**1.1**	cao
			Alternative solution N2L for car $6000-800-T=1400a$ N2L for trailer $T-300=400a$	**M1**		Attempt at N2L for at least one part of the system Do not allow for weight used instead of mass. Allow sign errors. All forces included and no extras (Use the mass to determine which part of the system considered)
			Add equations to give	**M1**		Attempt to eliminate T from their two equations
			$a=2.72\,\text{m s}^{-2}$ (to 3 s.f.)	**A1**		cao
				[3]		

Question			Answer	Marks	AO	Guidance
3	(a)		Resolve horizontally $F = 12\sin 20$	M1	1.1a	Resolving horizontally – allow sin/cos interchange. Allow if $F = T\sin 20$ or similar seen
			$F = 4.10$	A1	1.1	www
				[2]		
3	(b)		Resolve vertically $[mg =]12\cos 20$	M1	3.1b	Resolve to find vertical component of tension. Allow sin/cos interchange if consistent with (a) If triangle of forces used, allow attempt to find by Pythagoras
			$m = \frac{12\cos 20°}{g} = 1.15\,\text{kg}$	M1	3.4	Equating weight to their component of tension and dividing their weight by g soi
				A1	1.1	cao
				[3]		

Question			Answer	Marks	AO	Guidance
4			$3(2a\mathbf{i}+b\mathbf{j})+(b\mathbf{i}-3\mathbf{j})$ $[=22\mathbf{i}-9\mathbf{j}]$	**M1**	**1.1**	Attempt to scalar multiply $\mathbf{v}_1$ and add to $\mathbf{v}_2$ Allow vector expression or 2 separate components
			$6a+b=22$ and $3b-3=-9$	**M1**	**3.1a**	Equate coefficients of **i** and **j** to form two equations. Allow if **i** and **j** still seen in every term of these equations
			$a=4$	**A1**	**1.1**	cao
			$b=-2$	**A1**	**1.1**	cao
				[4]		

Question			Answer	Marks	AO	Guidance
5	(a)		$\log_{10}(y-k)=\log_{10}2^x$	M1	1.1	Correct use of one of the laws of logs – award if 2^x seen or if $(y-k)=10^{x\log 2}$
			$y=k+2^x$	A1	1.1	LHS must be $y=$ Allow $y=k+10^{x\log 2}$
				[2]		
5	(b)			B1	1.2	General shape correct. Positive and negative values of x should be seen used. FT their exponential (a)
				B1	1.1	y-intercept at $k+1$ on positive $y-$axis. FT their exponential (a) provided in terms of k
				B1	1.1	Asymptote at k. Horizontal line need not been seen provided the intention is clear
				[3]		

Question			Answer	Marks	AO	Guidance
6			$\frac{f(x+h)-f(x)}{h}=\frac{2(x+h)^2+3-(2x^2+3)}{h}$	**M1**	**2.1**	Uses the given function in the formula. Allow a slip eg missing brackets
			$=\frac{2x^2+4xh+2h^2+3-(2x^2+3)}{h}$	**M1**	**2.1**	Attempt to simplify the numerator
			$=4x+2h$	**A1**	**2.1**	Correct expression without h in the denominator from fully correct working
			$f'(x)=\lim_{h\to 0}(4x+2h)=4x$	**A1**	**2.1**	**AG** Correct use of limit as $h\to 0$ with their expression.
				[4]		

Question			Answer	Marks	AO	Guidance
7	(a)		Total in the AB direction is $3-3=0$			
			Total in the direction AD is $4+5-9=0$	**M1**	**2.1**	Considers forces in each direction
			So zero resultant force	**A1**	**2.1**	**AG** Allow if clear statement of zero force in two perpendicular directions, Do not allow for "equilibrium" on its own eg 3=3 and 4+5=9 is not sufficient without a comment
				[2]		
7	(b)		Take moments anticlockwise (N cm)	**B1**	**1.1**	At least one moment about the centre or any corner
			$4\times14-5\times14+3\times9-9\times14+3\times9$	**M1**	**1.1**	Combines moments of 5 forces about the centre. Allow only sign errors
			= –86 N cm			Do not allow as final answer
			= –0.86 [N m]	**A1**	**1.1**	Allow for 0.86 N m clockwise but not –0.86 N m clockwise Allow B1 SC1 for -0.86 Nm as the total moment about a different point.
				[3]		
7	(c)		The book will rotate	**B1**	**2.2a**	Allow turn or spin but not move, tilt or flip
			clockwise [about the centre of mass]	**B1**	**1.2**	Allow "there is a clockwise moment" for the second mark
				[2]		

Question			Answer	Marks	AO	Guidance
8	(a)		Using $\sin x \approx x$ and $\cos x \approx 1-\frac{1}{2}x^2$ $\sqrt{\sin 4x}+2\cos 2x \approx \sqrt{4x}+2\left(1-\frac{1}{2}(2x)^2\right)$	**M1**	**1.1**	Uses both given small angle approximations in the expression. Must see $\sqrt{4x}$ and $\frac{1}{2}(2x)^2$ or $\frac{1}{2}\times 4x^2$ condone missing brackets. Also allow for clear use of $\cos 2x = 1-2\sin^2 x$ and $\sin x \approx x$ used.
			So $y \approx 2\sqrt{x}+2-4x^2$	**A1**	**1.1**	**AG** Convincing argument to reach given answer
				[2]		
8	(b)		**DR** $\int_0^{0.1}\left(\sqrt{\sin 4x}+2\cos 2x\right)\mathrm{d}x$ $\approx \int_0^{0.1}\left(2x^{\frac{1}{2}}+2-4x^2\right)\mathrm{d}x$	**M1**	**3.1a**	Attempts to integrate the expression in powers of x Must be seen
			$=\left[\frac{2x^{\frac{3}{2}}}{\frac{3}{2}}+2x-\frac{4}{3}x^3\right]_0^{0.1}$	**A1** **A1**	**1.1** **1.1**	At least 2 correct terms (no FT from (a) as answer given) Fully correct indefinite integral. Need not be simplified
			$=\left(\frac{4}{3}0.1^{\frac{3}{2}}+0.2-\frac{0.004}{3}\right)-0=0.24083...$	**A1**	**1.1**	Correct value from correct indefinite integral. Allow for 0.24 or better if the method is clear. (Do not allow for 0.24059… which is obtained by integrating the original function by calculator.)
				[4]		

PTO for scheme using the trapezium rule

Question			Answer	Marks	AO	Guidance
8	(b)		**Alternative solution**			
			Use trapezium rule to find an area	**M1**		Also allow for a single trapezium
			Correct $\frac{h}{2}$ for the number of strips used	**A1**		Soi For example $\frac{0.1}{2}$ $\frac{0.05}{2}$, $\frac{0.025}{2}$, $\frac{0.01}{2}$ used for 1, 2, 4 10 strips
			At least 3 correct ordinates used	**A1**		Must be ordinates from the approximating function eg 2, 2.4372… and 2.5924… seen
			Area is approximately 0.24	**A1**		Accept awrt 0.24
				[4]		

Table of values

x	0	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09	0.1		0.025	0.075
actual y	2	2.199573	2.281092	2.342396	2.39275	2.435732	2.473165	2.506127	2.535317	2.561214	2.584167083		2.313465	2.52116
y from approx	2	2.1996	2.281243	2.34281	2.3936	2.437214	2.475498	2.50955	2.540085	2.5676	2.592455532		2.313728	2.525223

Answers

	using approx	using original function
1 strip	0.229623	0.229208
2 strips	0.236672	0.235817
4 strips	0.23931	0.239061
10 strips	0.240434	0.240194

Question			Answer	Mark	AO	Guidance
9	(a)		Using $v^2 = u^2 + 2as$ with $s = 0.8, u = 6, a = 9.8$ $v^2 = 6^2 + 2 \times 9.8 \times 0.8$	**M1**	**1.1a**	Allow for *suvat* equation(s) used leading to a value for v or v^2 Allow sign errors
			$v = \sqrt{51.68} = 7.19$ m s^{-1}	**A1** **[2]**	**1.1**	Allow even if the sign of u does not match the sign of s and a
9	(b)		Using $v^2 = u^2 + 2as$ with $s = 0.03, u = \sqrt{51.68}, v = 0$ $0^2 = 51.68 + 2 \times 0.03a$	**M1**	**3.1b**	Allow for *suvat* equation(s) used leading to a value for a Allow for $s = 3$ used. FT their (a) Allow sign errors
			$a = -861.3...$ m s^{-2}	**A1**	**1.1**	Need not be evaluated
			N2L for pebble (downwards positive) $0.04g - R = 0.04a$ $0.04g - R = -0.04 \times 861.3$	**M1** **A1**	**3.1b** **1.1**	Use of N2L allow one error or omission Fully correct equation FT their acceleration. Weight must be included.
			$R = 34.8$ N	**A1** **[5]**	**1.1**	Must be rounded to 3 sf. Accept 34.8 or 34.9 only
			Further Maths students may attempt an energy method for (b) Initial KE $= \frac{1}{2}mv^2 = \frac{1}{2} \times 0.04 \times 51.68$ GPE $= 0.04 \times 9.8 \times 0.03$ Work done against R is 1.04536 $R = \frac{1.04536}{0.03} = 34.8$ N	**M1** **A1** **A1** **M1** **A1**		Attempt to calculate change in KE or GPE Allow if GPE is not included

Question			Answer	Marks	AO	Guidance
10	(a)		When $t = 0, A = 8$ so $a = 8$ When $t = 1, A = 8.8$ so $b = 0.8$	**B1** **B1** **[2]**	**3.3** **3.3**	Allow embedded in $A = 8 + 0.8t$
10	(b)		$15 = 8 + 0.8t$ so $t = 8.75$	**B1** **[1]**	**3.4**	Allow for "after 9 days" oe FT their values in (a)
10	(c)		The model is linear so gives the same increase each day. 10% increase each day gives bigger increases as the size of the culture increases.	**B1** **[1]**	**3.5b**	Must indicate the mis-match between the linear model and the exponential observed results either in general terms or for a particular day (Amounts are 8, 8.8 and 9.6 for the model and 8, 8.8 9.68 for the 10% increase) (see appendix)
10	(d)		Using $A = Pe^{kt}$ when $t = 0$ gives $P = 8$ When $t = 1$, $8.8 = 8e^{1k}$ So $k = \ln 1.1 = [0.0953...]$	**B1** **M1** **A1** **[3]**	**3.3** **3.3** **3.3**	cao Forming an equation for k using $t = 1$ and $A = 8.8$ oe FT their value for P Allow for $\ln 1.1$ or a decimal answer to at least 2sf
10	(e)		Area 15 cm^2 when $15 = 8e^{(\ln 1.1)t}$ $t = \frac{\ln\left(\frac{15}{8}\right)}{\ln 1.1} = 6.60$	**M1** **A1** **[2]**	**3.4** **1.1**	Correct use of logs in an attempt to solve indicial equation Similarly for $15 = 8 \times 1.1^t$ FT their P and k
10	(f)		The model predicts unlimited growth which is not possible in the laboratory	**B1** **[1]**	**3.5b**	Must describe what the model predicts and compare with the situation being modelled (see appendix)

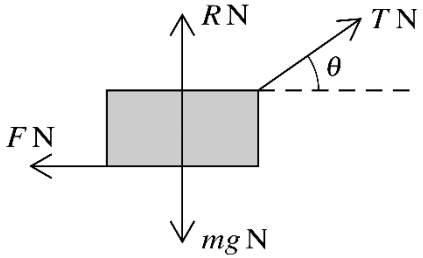
Question			Answer	Marks	AO	Guidance
11	(a)		If geometric, then $r = \frac{3k-6}{5k-2}$	M1	2.4	Allow instead for $r = \frac{k+2}{3k-6}$ or $r^2 = \frac{k+2}{5k-2}$ in any form Soi
			Common ratio gives $\frac{3k-6}{5k-2} = \frac{k+2}{3k-6}$ So $9k^2 - 36k + 36 = 5k^2 + 8k - 4$ So $k^2 - 11k + 10 = 0$	M1 A1	2.1 2.1	Forms an equation in k which need not be simplified **AG** Rearranges to correct three term quadratic. At least one intermediate step must be shown.
				[3]		**SC1** for showing $k = 1$ leads to $3, -3, 3$ ($r = -1$) and that $k = 10$ leads to 48, 24, 12 ($r = \frac{1}{2}$) and demonstrating that both are geometric
11	(b)		So $k = 1, 10$ When $k = 1$ the sum of 20 terms is $(3+(-3))+(3+(-3))+...+(3+(-3)) = 0$	M1 M1 A1	1.1a 3.1a 1.1	Solves the quadratic to give at least one root Soi Evaluating the terms of the sequence when $k = 1$ cao
			Alternative for the last 2 marks $S_{20} = \frac{3(1-(-1)^{20})}{1-(-1)} = 0$	M1 A1		Using the formula for the sum of terms of a GP with $r = -1$ cao
				[3]		
11	(c)		When $k = 10$ the sequence is $48, 24, 12\ldots$ So $a = 48, r = \frac{1}{2}$ $S_\infty = \frac{48}{1-\frac{1}{2}} = 96$	B1 B1	3.1a 1.1	Identifies the first term and common ratio soi cao
				[2]		

Question			Answer	Marks	AO	Guidance
12	(a)		$\mathbf{r} = \int \left(3\mathbf{i} + (6t^2 - 5)\mathbf{j}\right) \mathrm{d}t$	M1	1.1a	Attempt to integrate velocity either as a vector or 2 separate components
			$= 3t\mathbf{i} + (2t^3 - 5t)\mathbf{j} + \mathbf{c}$	A1	1.1b	Condone missing constant
			When $t = 0, \mathbf{r}_0 = 0\mathbf{i} + 7\mathbf{j}$	M1	1.1a	Either as a vector constant or 2 separate components evaluated. May be implied by correct vector answer
			So position is $= 3t\mathbf{i} + (2t^3 - 5t + 7)\mathbf{j}$	A1	2.5	Must be in vector form (could be column vector but must be exact vector notation eg brackets and not **i** and **j** as well) Allow $3t\mathbf{i} + (2t^3 - 5t)\mathbf{j} + 7\mathbf{j}$
				[4]		
12	(b)		Using $x = 3t$ and $y = 2t^3 - 5t + 7$	M1	3.1a	Attempt to eliminate *t* from the parametric equations
			We get $y = 2\left(\frac{x}{3}\right)^3 - 5\left(\frac{x}{3}\right) + 7$	A1	1.1	FT their (a) Isw
				[2]		

Question			Answer	Marks	AO	Guidance
13	(a)		$\frac{dy}{dx} = p - 16x^{-3}$	M1	3.1a	Uses negative powers to attempt to find expression for $\frac{dy}{dx}$ A term in x^{-3} needed for this mark.
			$p - 16x^{-3} = 0$ $p - 16 \times 2^{-3} = 0$	M1	1.1	Equates their derivative to zero and attempts to solve using $x = 2$
			$p = 2$	A1	1.1	
			When $x = 2, y = 7$ so $7 = 2p + \frac{8}{2^2} + q$ So $2p + q = 5$	M1	3.1a	Uses the given coordinates to link p and q, or their p and q in the Cartesian equation
			so $q = 1$	A1	1.1	FT their p
				[5]		
13	(b)		$\frac{d^2y}{dx^2} = 48x^{-4} = \left[\frac{48}{x^4}\right]$	B1	1.1	Allow even from wrong values of p and q
				[1]		
13	(c)		At (2, 7) $\frac{d^2y}{dx^2} = 48 \times 2^{-4} = [3] > 0$	M1	1.1	Substitutes $x = 2$ into their (b) Need not be fully evaluated Also allow for arguing the $48x^{-4}$ is always positive. Do not allow for gradient evaluated on either side of (2, 7)
			So the stationary point is a minimum	A1	2.2a	Clear statement using the positivity of the second derivative from correct working in (c). FT their second derivative (stating maximum if their value is negative)
				[2]		

Question			Answer	Marks	AO	Guidance
14	(a)		The size and shape of the ball are neglected	B1 [1]	2.4	Sensible comment equivalent to "the object is modelled as a point mass". Do not allow for a statement that includes correct and incorrect ideas. (see appendix)
14	(b)		Vertical motion $s = -3.6, a = -9.8, t = 2.4$ $s = u_y t + \frac{1}{2}at^2$ $-3.6 = 2.4u_y - 4.9 \times 2.4^2$ Giving $u_y = 10.26$ m s^{-1}	 M1 A1 [2]	 3.1b 1.1	 Use of *suvat* equation(s) with $s = \pm 3.6$ and $v \neq 0$ leading to a value for u_y Allow sign errors cao Allow SC1 if M0 awarded and $u \sin \alpha$ seen. Or award SC2 for $u \sin \alpha$ in (b) if 10.26 seen in (c)
14	(c)		The horizontal velocity of the ball must be the same as the velocity of the man $u = \sqrt{4^2 + 10.26^2} = 11.01$ $\alpha = \tan^{-1}\frac{10.26}{4} = 68.7°$	B1 B1 M1 A1	3.1b 1.1 1.1 1.1	Soi eg $u \cos \alpha = 4$ FT their (b) and their horizontal velocity Also allow from solving $u \cos \alpha = 4$ or $u \sin \alpha = 10.26$ FT their (b) and their horizontal velocity
			Alternative solution for last 3 marks $-3.6 = 2.4\frac{4}{\cos\alpha}\sin\alpha - 4.9 \times 2.4^2$ $\alpha = 68.7°$ So $u = \left[\frac{4}{\cos 68.7}\right] = 11.01$	 M1 A1 B1	 	 Substitute for u in terms of $\cos \alpha$ leading to a value for $\tan \alpha$ FT their horizontal velocity FT their value for α
				[4]		

Question			Answer	Marks	AO	Guidance
15			Circle is $(x+1)^2+(y-7)^2=25$	M1	3.1a	Attempts to complete the square for either x or y terms Soi
			So C is the point $(-1, 7)$	A1	2.1	Correct coordinates of the centre seen or used. Condone incorrect or missing radius
			The intersection of the line and circle at $(7y-25)^2+y^2+14y-50-14y+25=0$	M1	3.1a	Attempt to solve the equations simultaneously $[x^2+\left(\frac{x+25}{7}\right)^2+2x-14\left(\frac{x+25}{7}\right)+25=0]$or oe
			Giving $50y^2-350y+600=0$	M1	2.1	Simplifies equation leading to two roots. Allow arithmetic errors $[50x^2+50x-600=0]$
			So y = 3, 4	A1	1.1	Could be solved by calculator $[x=-4, 3]$
			A and B are $(-4, 3)$ $(3, 4)$	A1	1.1	FT their y values
			Gradients of AC and BC are $\frac{4}{3}$ and $\frac{3}{-4}$	M1 A1	3.1a 2.1	Attempt to find gradient(s) of at least one of these lines Both correct gradients (not OA or OB)
			The product of the gradients is -1 so the lines are perpendicular			
			So the triangle is right-angled	A1	2.2a	Clear argument based on perpendicular lines www
			Alternative for last three marks Distance $AB^2 = (-4-3)^2+(3-4)^2=50$	M1		Attempt to find the length of one of the sides of the triangle FT their coordinates
			$AC^2 = BC^2 = radius^2 = 25$	A1		All three correct lengths found
			So $AC^2 + BC^2 = 50 = AB^2$			
			So by Pythagoras the triangle is right-angled	A1		Clear argument based on Pythagoras' theorem or the cosine rule leading to a value for angle ACB www
				[9]		

Question			Answer	Marks	AO	Guidance
16	(a)					
			Resolve vertically $R = mg - T\sin\theta$	B1	3.1a	Must be explicit – may be seen on the diagram. Allow $R + T\sin\theta = mg$ if $F = \mu(mg - T\sin\theta)$ also seen
			Motion so $F = \mu R$ $F = \mu(mg - T\sin\theta)$	M1	3.3	Allow only if R seen explicitly or correct vertical equation seen Allow $F = \mu mg$ only if $R = mg$ seen explicitly or on the diagram
			Resolve horizontally $T\cos\theta - F = ma$ $ma = T\cos\theta - \mu mg + T\mu\sin\theta$	M1	3.1a	All forces correct and no extras. Allow sign errors
			$a = \frac{T}{m}\cos\theta - \mu g + \frac{T}{m}\mu\sin\theta$	A1	2.1	**AG** Complete argument needed
				[4]		

Question			Answer	Marks	AO	Guidance
16	(b)		$\frac{\mathrm{d}a}{\mathrm{d}\theta} = -\frac{T}{m}\sin\theta + \frac{T}{m}\mu\cos\theta$	M1	3.1a	Attempt to differentiate wrt θ
			$-\frac{T}{m}\sin\alpha + \frac{T}{m}\mu\cos\alpha = 0$	M1	1.1a	Equate their derivative to 0 and attempt to rearrange using a trig identity. Condone using θ not α
			$\frac{\sin\alpha}{\cos\alpha} = \mu$ so $\alpha = \tan^{-1}\mu$	A1	1.1	Must be $\alpha =$ Also allow for $\alpha = \frac{\pi}{2} - \tan^{-1}\frac{1}{\mu}$
			Alternative solution			
			Maximum a when $\frac{T}{m}(\cos\theta + \mu\sin\theta)$ is max			
			Acceleration is $(R\cos(\theta - \beta))$ where $\beta = \tan^{-1}\mu$	M1 M1		Uses trig identity Attempt to find the value of β
			Max acceleration when $(\alpha - \beta) = 0$			
			Giving $\alpha = \tan^{-1}\mu$	A1		Must be $\alpha =$ Also allow for $\alpha = \frac{\pi}{2} - \tan^{-1}\frac{1}{\mu}$
				[3]		

Exemplar responses for Q10(c)

Response	Mark
Larger values of *t* give inaccurate results	**B0**
Exponential doesn't give the same increase each day	**B0**
10% of the new area is not 10% of the original area	**B0**
Original model predicts an increase of 0.8 each day but the increase 10% each day so the model is an underestimate	**B1**
This model doesn't grow exponentially but increasing by 10% each day would be modelled by that	**B1**
The model is linear whereas 10% each day is exponential	**B1**

Exemplar responses for Q10(f)

Response	Mark
It would get too big	**B0**
It would get impossibly big	**B1**
There is no limit to the size of the area, but growth will eventually reduce or stop	**B0**
The area *would be* too large to be plausible and have to outgrow the lab (would be implies the model)	**B1 BOD**
For large values of *t*, the area would be too large (large values of *t* implies the model being used)	**B0**
For large values of *t*, the area would be impossibly large	**B1**
It suggests that the culture grows to a size that is unrealistic ("it" refers to the model)	**B1**
The model predicts unlimited growth but this is not possible	**B1**

Exemplar responses for Q14(a)

Response	Mark
The mass is concentrated at the centre	**B0**
The object has no mass	**B0**
There is no air resistance	**B0**
The weight acts at the centre [of mass]	**B0**
There is no spin	**B1**
The ball's size and shape do not matter	**B1**
Only its mass is taken into account so it doesn't spin	**B1**
The size of the ball is negligible and there are no external forces acting on the ball	**B0**
Point mass means there is no air resistance	**B0**
There is no air resistance because the object has no size	**B0**

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