OCR
Oxford Cambridge and RSA

GCE

Mathematics B MEI

H640/01: Pure Mathematics and Mechanics

A Level

Mark Scheme for June 2023

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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. **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	

5. **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			using *suvat* with upwards positive $u = 8, a = -9.8, s = 3$ $s = ut + \frac{1}{2}at^2$ $3 = 8t - 4.9t^2$ Solve $4 \cdot 9t^2 - 8t + 3 = 0$ $t = 0.584, 1.05$ s	**M1** **A1**	**3.4** **1.1b**	Using *suvat* equation(s) leading to a value for *t.* Allow sign errors both values needed. ISW if an inequality is given as the final answer Exact roots are $\frac{40 \pm \sqrt{130}}{49}$
				[2]		

Question			Answer	Marks	AO	Guidance
2			$x^2-x-12=(x-4)(x+3)$	B1	1.1a	both factors seen
			$\frac{5x+1}{x^2-x-12}=\frac{A}{x-4}+\frac{B}{x+3}$	M1	1.1a	setting up partial fractions using their factors. May be implied by correct expression as final answer.
			$5x+1=A(x+3)+B(x-4)$			
			Substitute $x=-3$	M1	1.1b	method for finding either A or B soi
			giving $B=2$			
			substitute $x=4$ giving $A=3$	A1	1.1b	both A and B correct if clear which denominator they apply to
			$\frac{5x+1}{x^2-x-12}=\frac{3}{x-4}+\frac{2}{x+3}$			ISW if an error made only in the transcription to final answer
				[4]		

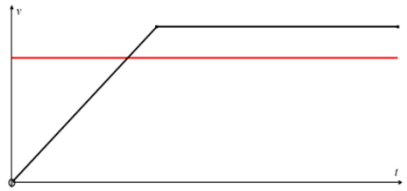
Question			Answer	Marks	AO	Guidance
3			$\int\left(2x^4-x\sqrt{x}\right)\mathrm{d}x=\int\left(2x^4-x^{3/2}\right)\mathrm{d}x$	M1	3.1a	Expresses integrand in index form soi
			$\frac{2x^5}{5}-\frac{x^{5/2}}{5/2}[+c]$	M1	1.1b	Integrates at least one term
			$\frac{2x^5}{5}-\frac{2x^{\frac{5}{2}}}{5}+c$	A1	1.1b	Any form. Arbitrary constant must be seen. Correct answer for the second term by a different method implies the first M1
				[3]		

Question			Answer	Marks	AO	Guidance
4	(a)		Weight acts through the centre of the ruler 15cm from P	B1	1.1a	Uses uniformity of the ruler, by distance shown on diagram or 15 used in a calculation or equation
			Take moments about P			
			$0.02g \times 15 = F \times 4$	M1	3.1b	Taking moments about any suitable point with all relevant forces and distances attempted. Must include a weight (not mass only) term. Allow one incorrect distance used. Allow 20g for weight or error in converting mass to kilograms or lengths to another unit.
			$F = \frac{0.02g \times 15}{4}$			
			$= \frac{3g}{40} = 0.735$	A1	1.1b	Allow $0.075g$
				[3]		
4	(b)		Without F the ruler would rotate clockwise [about P]	E1	2.4	Must indicate the turning effect of the weight and the direction. "Clockwise" implies rotation.
				[1]		

Question			Answer	Marks	AO	Guidance
5	(a)		**DR** $\frac{dy}{dx} = -2x + 32x^{-3} = 0$ $x^4 = 16$ So $x = \pm 2$ When $x = \pm 2, y = 7$ [So the points are $(-2, 7)$ and $(2, 7)$]	**M1** **A1** **A1**	**1.1a** **1.1b** **1.1b**	Attempt to differentiate and equate to zero soi Both x-values and no others. FT their x-coordinate(s) Do not FT $x = 0$
				[3]		
5	(b)		**DR** $\frac{d^2y}{dx^2} = -2 - 96x^{-4}$ When $x = 2, \frac{d^2y}{dx^2} = -2 - \frac{96}{16} < 0$ When $x = -2, \frac{d^2y}{dx^2} = -2 - \frac{96}{16} < 0$ So both points are maximum points	**M1** **E1**	**2.1** **2.1**	Attempts to find the second derivative. FT their $\frac{dy}{dx}$ Or convincing statement that $\frac{d^2y}{dx^2} < 0$ for any $x[\neq 0]$ because x^{-4} is always positive **AG** Complete argument required from correct second derivative and their $x \neq 0$. ISW if $-2 - \frac{96}{x^4}$ wrongly evaluated. Also allow for one point established and an argument from symmetry
			Alternative method $\frac{dy}{dx} > 0$ for $0 < x < 2$ and $\frac{dy}{dx} < 0$ for $x > 2$ and $\frac{dy}{dx} > 0$ for $x < -2$ and $\frac{dy}{dx} < 0$ for $-2 < x < 0$ So both points are maximum points	**M1** **E1**		Evaluating gradient for suitable values of x on either side of each turning point Also allow for y-coordinates in these ranges. AG Complete argument required from correct first derivative and their $x \neq 0$. Also allow for one point established and an argument from symmetry
				[2]		

Question			Answer	Marks	AO	Guidance
6	(a)		$\sin x\cos\frac{\pi}{6}+\cos x\sin\frac{\pi}{6}$ $=\cos x\cos\frac{\pi}{4}+\sin x\sin\frac{\pi}{4}$	M1	2.1	Using a compound angle formula at least once
			$\frac{\sqrt{3}}{2}\sin x+\frac{1}{2}\cos x=\frac{\sqrt{2}}{2}\cos x+\frac{\sqrt{2}}{2}\sin x$	M1	2.1	Uses exact values for at least 2 trigonometric terms
			$\sin x\left(\frac{\sqrt{3}}{2}-\frac{\sqrt{2}}{2}\right)=\cos x\left(\frac{\sqrt{2}}{2}-\frac{1}{2}\right)$	M1	2.1	Collecting terms and factorising
			$\tan x=\frac{\sqrt{2}-1}{\sqrt{3}-\sqrt{2}}$	E1	2.1	**AG** Complete argument with proper use of brackets where necessary
				[4]		
6	(b)		$x=\frac{7\pi}{24},\frac{31\pi}{24}$	B1	1.1b	Allow for both values without working and no others in the range $0\leq x\leq 2\pi$. Allow decimal equivalents 0.916, 4.06 or better
				[1]		

Question			Answer	Marks	AO	Guidance
7			Line through (4, 5) and (6, –1) has gradient $\frac{-1-5}{6-4}=-3$ So the equation is $y=17-3x$	M1	3.1a	Attempt to find equation of the line using correct gradient formula
			Points of intersection when $2x^2-7x+1=17-3x$	M1	1.1a	Eliminating one variable
			$2x^2-4x-16=0$	M1	1.1b	oe Three term quadratic seen or implied by correct x-values
			$x=-2, 4$	A1	1.1b	cao
			when $x=4, y=5$ when $x=-2, y=23$	A1	1.1b	Both y-coordinates seen.
			distance between $(4, 5)$ and $(-2, 23)$ $\sqrt{(-2-4)^2+(23-5)^2}$	M1	1.1a	Uses distance formula for their points (not given points)
			$=6\sqrt{10}$	A1	1.1b	Must be exact (allow $\sqrt{360}$ oe)
				[7]		

Question			Answer	Marks	AO	Guidance
8	(a)		6 5.4  5	B1 B1 B1	3.3 3.3 3.3	Straight line segment with positive gradient from the origin Subsequent line segment horizontal and above the given line Gradient change in their graph labelled with 5 and 6. (May be on axes)
				[3]		
8	(b)		velocity of the boy [$t < 5$ s] $v = 1.2t = 5.4$ giving $t = 4.5$ s	M1 A1	3.1b 1.1b	Equates an expression for boy's velocity to 5.4 Mark final answer
				[2]		

8	**(c)**		Max distance when $t = 4.5$ boy travels $\frac{1}{2} \times 1.2 \times 4.5^2 = 12.15$ bus travels $4.5 \times 5.4 = 24.3$ m Max distance is 24. 3 – 12.15 =12.15 m	**M1** **M1** **A1**	**3.1b** **3.1b** **1.1b**	recognises that max distance occurs when speeds are equal. Allow for their $t < 5$ from (b) used. Allow for $u = 0$, $v = 5.4$ and $a = 1.2$ in $v^2 = u^2 + 2as$ attempt to use *suvat* or area under the graph and their time $t \leq 5$ to find distance travelled by boy. Cao
			Alternative method 1 Max distance gained by the bus ahead of the boy is represented by the area of the triangle on velocity-time graph Distance $= \frac{1}{2} \times 5.4 \times 4.5 = 12.15$ m	 **M1** **M1** **A1**		 recognises that max distance occurs when the speeds are equal. Allow for their time from (b) used Attempt to find area of the triangle Cao
			Alternative method 2 Distance S at time t between $[t < 5]$ $[S =] 5.4t - \frac{1}{2} \times 1.2t^2$ Max occurs when $\frac{dS}{dt} = 5.4 - 1.2t = 0$ When $t = 4.5$, max distance is 12.15 m	 **M1** **M1** **A1**		 Combines expressions from *suvat* equations to find expression for the distance between Equates the derivative of their expression to zero leading to a value for t Cao
				[3]		

8	**(d)**		Let the time from start to catch the bus be T s			
			Boy's distance is area of trapezium $\frac{1}{2} \times 6(T + T - 5)[= 6T - 15]$	**B1**	**3.1b**	Expression for the total distance for the boy (area method) oe, e.g. sum of two distances $\frac{1}{2} \times 5 \times 6 + (T - 5) \times 6$
			Bus's distance $5.4T$ equate distances $5.4T = 6T - 15$	**M1**	**3.1b**	equates their expression for distance to the distance travelled by the bus and attempt to solve for T
			distance travelled in 25 s is 135 m	**A1**	**1.1b**	Cao. The value for T need not be seen explicitly
			Alternative method (relative speed)			
			At $t = 5$ the boy has travelled $\frac{1}{2} \times 5 \times 6 = 15$ m and the bus $5.4 \times 5 = 27$ m Boy needs to catch up 12 m	**B1**		12 m seen if clear that it is a distance between the boy and the bus
			Boy catches up 12 m at 0.6 ms^{-1} So time is $\frac{12}{0.6}$ [=20 s]	**M1**		Uses relative speed to find the time to catch up
			Total time 25 s gives distance 135 m	**A1**		Cao. 25 s need not be seen explicitly
			Alternative (numerical) method			
			Finds at least one correct distance for boy for $t > 5$	**B1**		
			Working towards the time and distance at which the distances are equal	**M1**		May be awarded for incorrect time and distances eg $0.6t^2$ used for the boy
			For 25 s distance travelled 135 m	**A1**		25 s must be seen as well as 135 m
			No method seen			SC2 for 135 m www where $t = 25$ not seen
				[3]		

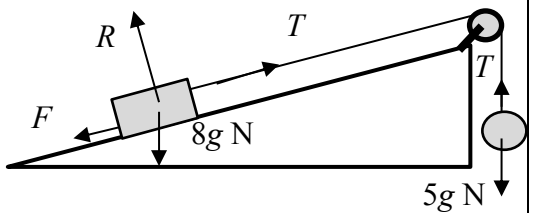
Question			Answer	Marks	AO	Guidance
9	(a)		$\frac{dy}{dx} = e^x - 4e^{-x} = 3$	M1	2.1	Equate to 3
			$(e^x)^2 - 3e^x - 4 = 0$	E1	2.1	AG Rearrange to quadratic in e^x Also allow $e^{2x} - 3e^x - 4 = 0$ Expression $= 0$ must be seen
				[2]		
9	(b)		Solve to give $e^x = [-1], 4$	M1	2.1	May be BC giving at least one root of the quadratic equation (a)
			When $e^x = 4, x = \ln 4$	A1	2.1	$x = \ln 4$ must be seen explicitly
			When $e^x = -1$ there are no real values of x, so no other points on the curve.	E1	2.1	must explain why they reject the value –1 for e^x, or state $e^x + 1$ is never zero
				[3]		
9	(c)		Equation $y = \int (e^x - 4e^{-x})\,dx$			
			$[y =] e^x + 4e^{-x} [+c]$	B1	3.1a	Condone missing $+c$ in their integral
			When $x = 0, y = 0 = 1 + 4 + c$	M1	3.1a	Attempt to evaluate c
			So $c = -5$ $[y = e^x + 4e^{-x} - 5]$	A1	1.1b	
			When $x = 1, y = e^1 + 4e^{-1} - 5$	M1	2.1	Substituting $x = 1$ into their expression
			$y = -0.810 < 0$ so below the x-axis	E1	2.1	AG must argue below the axis from correct y value. Must be clear that -0.81 is a y-coordinate
				[5]		

Question			Answer	Marks	AO	Guidance
10	(a)		Use $\sin^2 x = \frac{1}{2}(1 - \cos 2x)$ So $1.5 + \sin^2 x = 1.5 + \frac{1}{2}(1 - \cos 2x)$ So $y = 2 - 0.5\cos 2x$	M1 A1	2.1 2.1	attempt to write $\sin^2 x$ in terms of $\cos 2x$ Allow for $a = 2,\ b = 0.5$ or fully correct expression
				[2]		
	(b)		[period] π	B1	1.2	Cao. Do not accept 180°
				[1]		
	(c)		intersect when $2 - 0.5\cos 2x = 1 + \cos 2x$ $\cos 2x = \frac{2}{3}$ $x = 0.421,\ 2.72,\ 3.56,\ 5.86$ radians (correct to 3sf)	M1 A1 A1	3.1a 1.1b 1.1b	Equate expressions in $\cos 2x$ and attempt to rearrange At least 1 correct value Three other correct values and no others in the interval $0 \le x \le 2\pi$ FT their first root
			Alternative method $1.5 + \sin^2 x = 2 - 2\sin^2 x$ Or $1.5 + (1 - \cos^2 x) = 1 + 2\cos^2 x - 1$ $3\sin^2 x = 0.5$ or $3\cos^2 x = 2.5$ $\sin x = \pm\sqrt{\frac{1}{6}}$ $[= \pm\frac{\sqrt{6}}{6}]$ or $\cos x = \pm\sqrt{\frac{5}{6}}$ $x = 0.421,\ 2.72,\ 3.56,\ 5.86$ radians (correct to 3sf)	 M1 A1 A1	 At least 1 correct value Four correct values and no others in the interval $0 \le x \le 2\pi$ FT their first root
				[3]		

Question			Answer	Marks	AO	Guidance
11	(a)	(i)	Substitute $t = 10,\ h = 10$ and $t = 85, h = 200$ $10 = a + b\ln 10$ $200 = a + b\ln 85$ Solve simultaneous equations to give $b = \left[\frac{190}{\ln\frac{85}{10}} = \frac{190}{2.14}\right] = 88.8$	M1 E1	3.3 2.1	Forms two equations and attempt to solve simultaneously (BC) Allow if $10 = a + 2.303b$ and $200 = a + 4.443b$ used AG must be 3 s.f. If by simultaneous equations solved BC, 88.78…..or better must also be seen
				[2]		
11	(a)	(ii)	$a = -194$	B1	3.3	Accept awrt -194 or -195
				[1]		
11	(b)	(i)	For small values of *t* the model for *h* predicts a negative height [which is not possible]	E1	3.5b	argument based on negativity
				[1]		
11	(b)	(ii)	The model predicts that the sunflower would continue to increase in height for ever, which is not possible	E1	3.5b	argument based on contrast between ever increasing height predicted by the model and reality
				[1]		

11	**(c)**		height at $\frac{85}{2}$ days $a+88.8\ln\frac{85}{2}$ cm	**M1**	**3.4**	Also allow for 84.5 days used for 85
			[using given answers above] 139 cm which is more than 1 m	**E1**	**2.2a**	Established using a value of h between 137.9 and 139 needed.
			Alternative method time to reach 1 m: $100=a+88.8\ln t$	**M1**		Equate to 100 and solve for t. Condone $h=1$ used
			[using given answers above] 27.4 days which is less than $\frac{85}{2}$	**E1**		Established using a value of t between 27 and 28 needed.
				[2]		
11	**(d)**		rate of growth $\frac{\mathrm{d}h}{\mathrm{d}t}=\frac{b}{t}$	**M1**	**3.1b**	Attempt to differentiate to give expression of the form $\frac{k}{t}$
			rate 3 cm per day when $\frac{b}{t}=3$	**M1**	**3.4**	equates their derivative to 3
			$t=\frac{b}{3}=29.6$	**A1**	**1.1b**	allow 29 or 30 days
				[3]		

Question			Answer	Marks	AO	Guidance
12	(a)		Weight = $-2g\mathbf{j}$ N [$=-19.6\mathbf{j}$ N]	B1	2.5	Allow equivalent column vectors in all part questions
				[1]		
12	(b)		horizontal force $3\mathbf{i}$	B1	3.3	May be implied by correct resultant force
			Newton's second law $(-4\mathbf{i}+12\mathbf{j})+3\mathbf{i}-19.6\mathbf{j}=2\mathbf{a}$	M1	1.1a	Must be vector equation. allow one missing or incorrect force.
			$\mathbf{a}=-0.5\mathbf{i}-3.8\mathbf{j}$ m s^{-2}	A1	1.1b	ISW if the magnitude is also given
			Alternative method Horizontal motion $-4+3=2a_x$ Vertical motion $12-19.6=2a_y$	B1 M1		3 N force used in the horizontal equation and not used in the vertical equation Considers motion in two directions. Allow one missing or incorrect force
			$\mathbf{a}=-0.5\mathbf{i}-3.8\mathbf{j}$ m s^{-2}	A1		ISW if the magnitude is also given
				[3]		
12	(c)		$v=\mathbf{u}+\mathbf{a}t$ $=5\mathbf{i}+(-0.5\mathbf{i}-3.8\mathbf{j})\times 4$	M1	1.1a	Using *suvat* equation(s) leading to a vector **v**. Do not award if scalar added to vector
			$=3\mathbf{i}-15.2\mathbf{j}$ m s^{-1}	A1	1.1b	Mark final answer. Must be vector **v** and not speed. FT their vector acceleration
				[2]		
12	(d)		constant velocity is equilibrium so $(\mathbf{i}+7.6\mathbf{j})$ N	B1	1.1b	Cao. ISW if the magnitude is also given
				[1]		

Question			Answer	Marks	AO	Guidance
13	(a)			B1 B1 B1 B1	1.1b 1.1b 1.1b 1.1b	(Each force must have correct direction) Matching tensions on the sphere and the block (may also include tensions on the pulley) Normal reaction. Allow without label or $8g\cos 15°$ used Friction in the correct direction and labelled This could be $0.3 \times 8g\cos 15°$ oe Both weights correct. Do not award if weight and its components shown together (unless dotted or similar) or any other extra forces
				[4]		
13	(b)		Sphere (downwards positive) $5g - T = 5a$	 M1 A1	 1.1a 1.1b	 Newton's second law allow sign errors All correct – accept $49 - T = 5a$ Any form
				[2]		
13	(c)		$R = 8g\cos 15°$ $F = 0.3R = 2.4g\cos 15°$ Newton's second law for the block $T - 8g\sin 15° - F = 8a$ Add equations of motion $5g - 8g\sin 15° - 2.4g\cos 15° = 13a$ $a = 0.461$	B1 M1 M1 A1 M1 A1	3.1b 3.4 1.1a 1.1b 1.1a 1.1b	 FT their R Allow one missing or incorrect force, must be dimensionally correct. FT their F All correct FT their F Attempt to eliminate T This equation with one missing or incorrect force implies the previous M1A0M1
				[6]		

Question			Answer	Marks	AO	Guidance
14	(a)		$\log_{10}200 - \log_{10}20 = \log_{10}\frac{200}{20} = 1$ $= \log_{10}10 = 1$	M1 A1	1.1a 1.1b	uses laws of logs AG $\log\frac{200}{20}$ or $\log_{10}10$ must be seen explicitly
			Alternative method $\log_{10}20 = \log_{10}2 + \log_{10}10$ $\log_{10}200 = \log_{10}2 + \log_{10}100$ So $\log_{10}200 - \log_{10}20 = 2 - 1 = 1$	M1 A1		Uses laws of logs Must see $\log_{10}100 = 2$ or $\log_{10}10 = 1$ explicitly
				[2]		
14	(b)		$\log_{10}2000 - \log_{10}200 = \log_{10}\frac{2000}{200} = 1$ same as the difference for the first two terms, so an arithmetic sequence	M1 A1	2.1 2.1	Attempts to establish a common difference of 1 argues from a common difference eg "increases by 1 each time". Must use exact values to establish the difference between the second and third terms.
			Alternative method $\log_{10}20 = \log_{10}10 + \log_{10}2 = 1 + \log_{10}2$ $\log_{10}200 = \log_{10}100 + \log_{10}2 = 2 + \log_{10}2$ $\log_{10}2000 = \log_{10}1000 + \log_{10}2 = 3 + \log_{10}2$ which is arithmetic with first term $\log_{10}20$ and common difference of 1	M1 A1		rewrites two more terms of the sequence and makes a comparison argues from a common difference eg "increases by 1 each time" Must use exact values to establish the difference between the second and third terms.
				[2]		
14	(c)		$S_{50} = 25(2a + (n-1)d)$ or $25(a + l)$ $S_{50} = 25(2(\log_{10}20) + 49 \times 1)$	M1 A1	1.1a 1.1b	Uses the formula with first term $\log_{10}20$ and common difference 1 Allow for fully correct expression not simplified. isw Correct forms include $50\log_{10}20 + 1225$, $25\log 400 + 1225$, $25(\log 400 + 49)$, $25(\log 4 + 51)$ etc
				[2]		

Question			Answer	Marks	AO	Guidance
15	(a)		vertical motion with $u\sin\theta,\ a=-g,\ s=0$ $0=u\sin\theta t-\frac{1}{2}gt^2$ $t=0,\ \frac{2u\sin\theta}{g}$	M1	2.1	*suvat* equations used with $u\sin\theta$ leading to an expression for the time of flight. Do not allow for time to the top unless subsequently doubled.
			horizontal distance R given by $t=\frac{2u\sin\theta}{g},\ R=u\cos\theta\times\frac{2u\sin\theta}{g}$	M1	2.1	horizontal motion with $u\cos\theta,\ a=0$ and their expression for t soi Allow sin/cos interchange if consistent with their vertical equation
			$R=\frac{2u^2\sin\theta\cos\theta}{g}$	A1	2.1	Convincing argument AG Note M0M1A0 for sin/cos interchange
			Alternative method Substitute $t=\frac{x}{u\cos\theta}$ to form equation of the trajectory $y=u\sin\theta\times\frac{x}{u\cos\theta}-\frac{1}{2}g\left(\frac{x}{u\cos\theta}\right)^2$	M1		Allow equivalent formula quoted
			Equate y to zero and attempt to rearrange	M1		Allow sin/cos interchange if consistent with their horizontal equation
			$R=\frac{2u^2\sin\theta\cos\theta}{g}$	A1		Convincing argument AG
				[3]		

15	**(b)**		Max height H when $v_y = 0$			
			$0 = (u\sin\theta)^2 - 2gH$	**M1**	**3.1b**	*suvat* equation(s) with $v_y = 0$ leading to an equation for H not involving t. Allow sin/cos interchange if consistent with their (a)
			$H = \dfrac{u^2\sin^2\theta}{2g}$	**A1**	**1.1b**	correct expression for H
			Max height exceeds range when			
			$\dfrac{u^2\sin^2\theta}{2g} > \dfrac{2u^2\sin\theta\cos\theta}{g}$	**M1**	**1.1a**	Compares their H with given R Allow = used to find boundary value
			$\tan\theta > 4$	**M1**	**1.1a**	simplifies the inequality to an inequality for $\tan\theta$ (or equation)
			$76.0° < \theta\,[< 90°]$	**A1**	**1.1b**	must be an inequality for θ. Do not penalise for omission of 90°
				[5]		

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