GCE

Mathematics B (MEI)

H640/01: Pure Mathematics and Mechanics

Advanced GCE

Mark Scheme for November 2020

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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.

Text Instructions

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
E	Explanation mark 1
SC	Special case
^	Omission sign
MR	Misread
BP	Blank page
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 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 indicates that the instruction **In this question you must show detailed reasoning** appears in the question.

Subject-specific Marking Instructions for AS Level Mathematics B (MEI)

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:

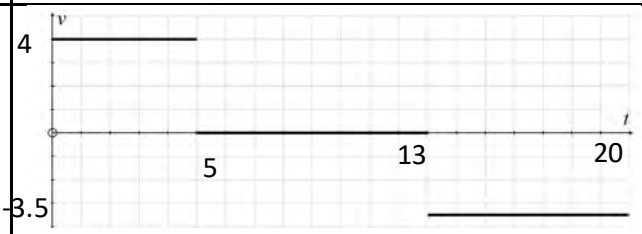
- If one attempt is clearly indicated as the one to mark, or only one is left uncrossed out, then mark that attempt and ignore the others.
- If more than one attempt is left not crossed out, then mark the last attempt unless it only repeats part of the first attempt or is substantially less complete.
- 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.

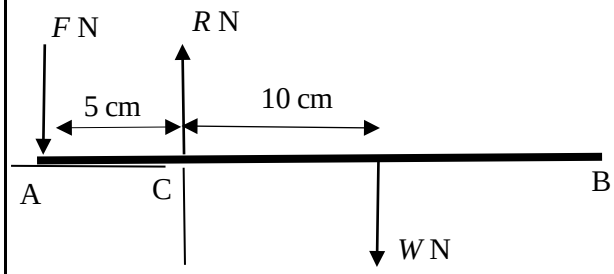
h For a genuine misreading (of numbers or symbols) which is such that the object and the difficulty of the question remain unaltered, mark according to the scheme but following through from the candidate's data. A penalty is then applied; 1 mark is generally appropriate, though this may differ for some 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.

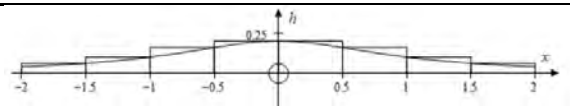
i If a calculator is used, some answers may be obtained with little or no working visible. Allow full marks for correct answers provided that there is nothing in the wording of the question specifying that analytical methods are required such as the bold "In this question you must show detailed reasoning", or the command words "Show" and "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	AOs		Guidance
1			$\left(\frac{27}{x^9}\right)^{\frac{2}{3}} \times \left(\frac{x^4}{9}\right) = \left(\frac{9}{x^6}\right) \times \left(\frac{x^4}{9}\right) = \frac{1}{x^2}$	M1 A1 [2]	1.1a 1.1	$\frac{1}{x^6}$ soi Fully simplified. Allow x^{-2} oe	
2			$\frac{\left(a+\sqrt{2}\right)\left(3+\sqrt{2}\right)}{\left(3-\sqrt{2}\right)\left(3+\sqrt{2}\right)}$ $= \frac{3a+a\sqrt{2}+3\sqrt{2}+2}{9-2}$ $= \frac{3a+2}{7} + \frac{a+3}{7}\sqrt{2}$	M1 M1 A1 [3]	1.1a 1.1a 1.1	Attempt to rationalize the denominator Attempt to expand the brackets must be in the form $p+q\sqrt{2}$ Mark final answer	Allow for instead stating $p = \frac{3a+2}{7}$, $q = \frac{a+3}{7}$
3			$\overrightarrow{AB} = \mathbf{b} - \mathbf{a} = \begin{pmatrix} -4 \\ 2 \\ 9 \end{pmatrix}$ distance $= \sqrt{(-4)^2 + 2^2 + 9^2} = \sqrt{101}$	B1 M1 A1 [3]	2.1 2.1 2.1	**AG** Soi Allow for $\overrightarrow{BA}$ even if wrongly labelled Attempt to find magnitude of their displacement vector cao AG	Do not allow final mark when there are missing brackets eg $-4^2 + 2^2 + 9^2$

Question			Answer	Marks	AOs		Guidance
4			$\frac{dy}{dx} = 4\left(x^2+5\right)^3 \times 2x = 8x\left(x^2+5\right)^3$	M1 A1	1.1a 1.1	Attempting to use the chain rule Any form	For candidates who have fully expanded the brackets and differentiate a polynomial without factorising, give SC1 for each correct term of the second derivative $56x^6+600x^4+1800x^2+1000$
			Using product rule with $u = 8x \quad v = \left(x^2+5\right)^3$	M1	1.1a	Need not be written explicitly FT their $\frac{dy}{dx}$ of correct form	
			$\frac{d^2y}{dx^2} = 8\left(x^2+5\right)^3 + 8x \times 3\left(x^2+5\right)^2 \times 2x$	A1	1.1	Any form	
			$= 8\left(x^2+5\right)^3 + 48x^2\left(x^2+5\right)^2$				
			$= 8\left(x^2+5\right)^2\left(7x^2+5\right)$	A1 [5]	1.1	Must be factorised – allow for $\left(x^2+5\right)^2\left(56x^2+40\right)$	
5	(a)			B1 B1 [2]	1.1 1.1	Graph from 3 horizontal line segments. Correct velocities labelled Times seen – either t = 5, 13, 20 or lengths of line segments 5, 8, 7 seen.	Any lines joining the horizontal lines should be vertical
5	(b)		Distance = $(4\times5)+(7\times3.5)$ m $= 44.5$	M1 A1 [2]	1.1a 1.1	finding the area of at least one region from their graph oe cao	May work directly from the information in the question without reference to their graph
5	(c)		Displacement = $20 - 24.5 = -4.5$ m	B1 [1]	1.1	Allow for –4.5 m or for 4.5 m south	Do not allow -4.5 m south

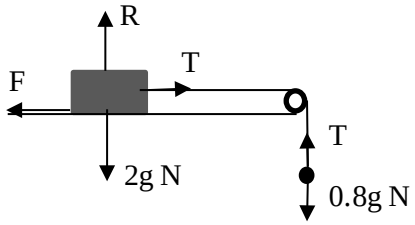
Question			Answer	Marks	AOs		Guidance
6	a			B1 B1 [2]	1.1a 1.1	F and their weight even if not labelled in roughly correct position Distances labelled. Allow for 5cm **and** any measurements that show that the weight is acting in the centre of the ruler.	R is already drawn in Printed Answer Booklet
6	(b)		Take moments about C $10\times 0.028g = 5F$ $F = 0.549$ N	M1 A1 [2]	1.1a 1.1	Moments about any point with all relevant forces seen. Allow their weight and one incorrect distance allow $\frac{7}{125}g$ oe	[Value of R is 0.8232 N]
7	(a)		**DR** $f(-2) = (-2)^3 + (-2)^2 - 8(-2) - 12 = 0$ so [by the factor theorem] $(x+2)$ is a factor	M1 A1 [2]	1.1a 2.2a	Substitution seen. Do not allow for division here Clear conclusion.	
7	(b)		**DR** $f(x) = (x+2)(x^2 - x - 6)$ $f(x) = (x+2)^2(x-3) = 0$ so $x = 3$ or $x = -2$ [repeated]	M1 A1 B1 A1 [4]	3.1a 1.1 1.1 2.1	Attempt to divide or factorise Correct quadratic factor seen Product of linear factors seen Do not allow without full working	Also allow M1 A1 for $f(x) = (x-3)(x^2+4x+4)$ if $(x-3)$ also established as a factor by division or factor theorem.

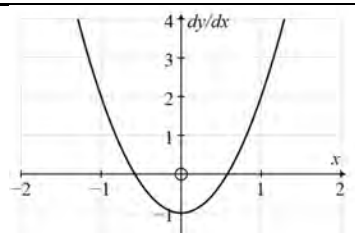
Question			Answer	Marks	AOs		Guidance
8	(a)		 x | 0 | ± 0.5 | ± 1 | ± 1.5 | 2 h | $\frac{1}{5}$ | $\frac{4}{25}$ | $\frac{1}{10}$ | $\frac{4}{65}$ | $\frac{1}{25}$ h | 0.2 | 0.16 | 0.1 | 0.061538 | 0.04 $= 2 \times 0.5(0.2 + 0.16 + 0.1 + 0.061538)$ =0.522 to 3sf	**M1** **M1** **A1** **[3]**	**3.4** **1.1a** **1.1**	Finding at least 2 distinct values for h Need not be a table of values Using rectangles forming UB for area with width 0.5. Need not be drawn	Allow both M marks if only half the area considered.
8	(b)		Area $\approx \frac{0.5}{2}(0.2 + 0.04 + 2(0.16 + 0.1 + 0.061538))$ =0.221 (to 3 sf)	**M1** **A1** **[2]**	**1.1a** **1.1**	Using trapezium rule with 5 h values FT incorrect h values for the M mark Allow awrt 0.22	Using the definite integral functionality of calculator gives 0.2214297… So method must be seen.
8	(c)		Volume = $2 \times (0.2208 \times 10)$ $= 4.42\ \text{m}^3$	**M1** **A1** **[2]**	**1.1a** **1.1**	Condone missing factor of 2 for method mark FT part (b)	

Question			Answer	Marks	AOs		Guidance
9			$v = \int (0.8t + 0.5)\,\mathrm{d}t = 0.4t^2 + 0.5t + c$	M1	3.1b	Attempt to integrate, condone omission of +c	
			When $t = 0, \quad v = 3$ $3 = 0.4 \times 0^2 + 0.5 \times 0 + c$	M1	3.1b	Attempt to evaluate c	
			So $v = 0.4t^2 + 0.5t + 3$	A1	1.1	Any form	
			Particle stationary when $v = 0$ $0.4t^2 + 0.5t + 3 = 0$	M1	3.1b	Forming an equation using their $v = 0$	
			discriminant $0.5^5 - 4 \times 0.4 \times 3 = -4.55 < 0$	M1	3.1a	Use of discriminant or completing the square, showing equation has complex roots or stating that the equation has no real roots	Allow this M mark for solving their equation if it has real solutions
			So the velocity is never zero and the particle never stationary.	E1 [6]	2.2a	Clear conclusion in context consistent with their working. FT their v. Dependent on at least 1 method mark.	Ignore any reference to $t < 0$ but do not allow stationary at $t = 0$
			OR $v = \int (0.8t + 0.5)\,\mathrm{d}t = 0.4t^2 + 0.5t + c$	M1 M1		Attempt to integrate, condone omission of +c Attempt to evaluate c	
			When $t = 0, \quad v = 3$ $3 = 0.4 \times 0^2 + 0.5 \times 0 + c$	A1			
			So $v = 0.4t^2 + 0.5t + 3$	M1		Uses the positivity of t to establish the positivity of v.	
			Clearly v is always positive therefore never sationary	M1 E1		Argues that v is always positive Clear conclusion in context consistent with their working. FT their v. Dependent on at least 1 method mark.	

Question			Answer	Marks	AOs		Guidance
			OR	**M1**		Attempt to construct an argument based on the positivity of *v*.	
			for $t > 0 \quad a = 0.8t + 0.5 > 0$	**M1**		Uses the positivity of *t* aiming to establish the positivity of *a*	
				A1		Clear argument that $a > 0$	
			So *v* is an increasing function	**M1**		Uses the link between $a > 0$ and *v*	
			When $t = 0, v = 3 > 0$ $v[> 3] > 0$ for all values of *t*	**M1**		Uses $v_0 = 3$ explicitly in their argument	
			So the velocity is never zero and the particle never stationary.	**E1** **[6]**		Convincing complete argument.	

Question			Answer	Marks	AOs		Guidance
10	(a)		**DR** $\frac{dx}{dt} = -2t^{-3}$ and $\frac{dy}{dt} = -3t^{-4} + t^{-2}$ So $\frac{dy}{dx} = \frac{-3t^{-4} + t^{-2}}{-2t^{-3}}$ Multiply top and bottom by t^4 $\frac{dy}{dx} = \frac{-3 + t^2}{-2t} = \frac{3 - t^2}{2t}$	**M1** **M1** **A1** **[3]**	**2.1** **2.1** **2.1**	Attempt to differentiate both equations Combining derivatives for $\frac{dy}{dx}$ AG Correct derivative in required form.	Note that $\frac{dy}{dx} = \left(-\frac{3}{t^4} - \frac{1}{t^2}\right) \times \left(-\frac{t^3}{2}\right)$
10	(b)		**DR** tangent parallel when $\frac{dy}{dx} = -\frac{1}{4}$ $\frac{3 - t^2}{2t} = -\frac{1}{4}$ $4t^2 - 2t - 12 = 0$ roots $2, \left[-\frac{3}{2}\right]$ [but since $t > 0$ $t = 2$] When $t = 2$, $x = \frac{1}{4}$, $y = \frac{1}{8} - \frac{1}{2} = -\frac{3}{8}$ So the coordinates are $\left(\frac{1}{4}, -\frac{3}{8}\right)$	**B1** **M1** **A1** **[3]**	**3.1a** **1.1a** **1.1**	Establishing gradient $-\frac{1}{4}$ Forming and solving quadratic equation. Using the value of *t* for both coordinates	$y = -\frac{1}{4}x + \frac{1}{4}$ not sufficient on its own Ignore any point based on $t = -\frac{3}{2}$

Question			Answer	Marks	AOs		Guidance
10	(c)		**DR** Rearrange $t = x^{-\frac{1}{2}}$ Substitute $y = \left(x^{-\frac{1}{2}}\right)^{-3} - \left(x^{-\frac{1}{2}}\right)^{-1} = x^{\frac{3}{2}} - x^{\frac{1}{2}}$ $= x^{\frac{1}{2}}(x-1) = (x-1)\sqrt{x}$	**B1** **M1** **A1** **[3]**	**3.1a** **1.1** **1.1**	or equivalent eg $\frac{1}{t} = \sqrt{x}$ Attempt to eliminate t factorised form. Allow surd or index form	$y = \frac{1}{\left(\frac{1}{\sqrt{x}}\right)^3} - \frac{1}{\left(\frac{1}{\sqrt{x}}\right)}$ Do not allow for $= \pm(x-1)\sqrt{x}$
11	(a)			**B1** **B1** **B1** **[3]**	**1.1a** **1.1a** **1.1a**	both weights correct. common tension in the rigtht directions Friction and normal reaction and no extra forces	Allow weight of box and weight of sphere, but not if both marked weight. Allow T_1 and T_2 provided they are clearly shown equal to each other elsewhere. For F,allow $0.35R$, $0.35\times 2g$ $0.7g$ or 6.86 N
11	(b)		$T - F = 2a$ $0.8g - T = 0.8a$	**B1** **B1** **[2]**	**1.1a** **1.1a**	Allow any expression for F Allow distinct tensions if consistent with diagram	For F,allow $0.35R$, $0.35\times 2g$ $0.7g$ or 6.86 N
11	(c)		Vertically for the block $R = 2g$ Friction $F = 0.35R = 0.7g$ Add equations $0.8g - F = 2.8a$ $0.8g - 0.7g = 2.8a$ $a = 0.35$ m s^{-2}	**M1** **A1** **M1** **A1** **[4]**	**3.1b** **2.1** **2.1** **2.1**	Attempt to use μ to evaluate friction Correct value for F Eliminate T from their equations AG must follow from correct work	Some of this work may already have been seen in previous part
11	(d)		Use $s = 0.5$, $u = 0$, $a = 0.35$ $0.5 = \frac{1}{2}\times 0.35\times t^2$ $t = 1.69$ s	**M1** **A1** **[2]**	**1.1a** **1.1**	Using *suvat* equation(s) leading to a value for t Do not allow ± 1.69	

Question			Answer	Marks	AOs		Guidance
12	(a)		$\frac{f(x+h)-f(x)}{h}=\frac{(x+h)^3-(x+h)-(x^3-x)}{h}$	M1	2.1	Substituting into $\frac{f(x+h)-f(x)}{h}$ and attempt to expand $(x+h)^3$	
			$=\frac{x^3+3hx^2+3h^2x+h^3-x-h-(x^3-x)}{h}$	A1	2.1	Correct expansion of $(x+h)^3$	Allow correct 6 terms not simplified
			$=\frac{3x^2h+3xh^2+h^3-h}{h}=3x^2+3xh+h^2-1$	M1	2.1	Simplifying the fraction to eliminate a denominator	
			$f'(x)=\lim_{h\to 0}\frac{f(x+h)-f(x)}{h}$	E1	2.1	Must include the idea of limit as *h* tends to zero AG	
			$=\lim_{h\to 0}(3x^2-1+3xh+h^2)=3x^2-1$	[4]			
12	(b)			B1	1.1a	Correct shape with vertex on the negative *y*-axis	
				B1 (dep)	1.1	(0, -1) labelled and an indication the graph crosses the *x*-axis at $\left(\pm\frac{1}{\sqrt{3}},0\right)$	Allow without $\pm\frac{1}{\sqrt{3}}$ if clear that the points are between $(-1,0)$ and $(1,0)$
				[2]			
12	(c)		Point of inflection when $f''(x)=0$	M1	2.1	Equating their second derivative to zero	
			$f''(x)=6x=0$ has only one root $x=0$	A1	2.1	Must explain that this is the only point of inflection	
			When $x=0$, $f'(x)=-1\neq 0$ so the point of inflection is not a stationary point.	E1	2.1	Must prove that the point is not stationary from correct value for $f'(0)$	Also allow if shown that the stationary points are at $\left(\pm\frac{1}{\sqrt{3}},0\right)$
				[3]			

Question			Answer	Marks	AOs		Guidance
13	(a)		eg. Neglect air resistance Constant gravity Projectile is a particle	B1 [1]	1.2	One sensible statement.	Do not accept level ground
13	(b)		$u_x = 35\cos\theta$ giving $x = (35\cos\theta)t$	B1	3.3	Award seen in any form	
			$u_y = 35\sin\theta$ giving $y = (35\sin\theta)t - \frac{1}{2}gt^2$	B1	3.3	soi	
			Substitute for t	M1	3.3	Substituting for t in their equation for y	
			$y = (35\sin\theta)\left(\frac{x}{35\cos\theta}\right) - \frac{1}{2}g\left(\frac{x}{35\cos\theta}\right)^2$	A1	1.1	Award in any form ISW	
			$\left[y = x\tan\theta - \frac{x^2}{250\cos^2\theta}\right]$	[4]			
13	(c)		EITHER Using $s = 22.5$, $u = 35\sin\theta$, $v = 0$, $a = -9.8$ $v^2 = u^2 + 2as$	M1	3.1b	Using any *suvat* in y-direction with $v_y = 0$	
			$0 = (35\sin\theta)^2 - 2\times 9.8\times 22.5$	A1	1.1a	Correct equation for θ only	Either $\theta = 37°$ or $\cos\theta = \frac{4}{5}$, $\tan\theta = \frac{3}{4}$ may be used.
			$\sin\theta = 0.6$ [giving $\theta = 36.9°$]	A1	1.1	allow 37º	
			Use the trajectory with $x = 110$ $y = 110\times\tan\theta° - \frac{1}{250\cos^2\theta°}\times 110^2$	M1	3.1b	Allow in terms of θ FT their value for θ if used	Allow this M mark for $t = \frac{110}{35\cos\theta} = \frac{55}{14}$ used in a suitable equation for y
			$= 6.875$ So it goes over the wall	A1 E1 [6]	1.1 3.2a	Correct y value Conclusion in context from correct values	

Question			Answer	Marks	AOs		Guidance
			OR Using $s = 22.5,\quad u = 35\sin\theta,\quad v = 0,\quad a = -9.8$ $v^2 = u^2 + 2as$ $0 = (35\sin\theta)^2 - 2\times 9.8\times 22.5$ $\sin\theta = 0.6$ giving $\theta = 36.9°$ Use the trajectory with $y = 5$ $5 = x\tan\theta° - \frac{1}{2450}g\sec^2\theta° x^2$ $\frac{1}{160}x^2 - \frac{3}{4}x + 5 = 0$ $x = 7.089,\quad 112.9$ So particle is above the height of the wall between 7 m and 112.9 m away, so when $x = 110$ m so it does not hit the wall	**M1** **A1** **A1** **M1** **A1** **E1** **[6]**		Using any *suvat* in *y*-direction with $v_y = 0$ Correct equation for θ only allow 37º Allow in terms of θ FT their value for θ if used Both correct *x*-values Conclusion in context from correct values	Either $\theta = 37°$ or $\cos\theta = \frac{4}{5}$, $\tan\theta = \frac{3}{4}$ may be seen. Allow this M mark for roots of their $y = 5$ used in a suitable equation for *x*.

Question			Answer	Marks	AOs		Guidance
14	(a)		$h_{max} = 5.15 + 3.4 \times 1 = 8.55$ $h_{min} = 5.15 - 3.4 \times 1 = 1.75$ These are the correct *h* values for high and low tide	**B1** **[1]**	**3.4**	Choosing $\cos t = \pm 1$ to give both values must be seen Allow without further comment	Allow for using given h values to find $\cos t = \pm 1$ only if there is a comment that these are max and min values for cos*t*
14	(b)	(i)	When $t = 1$ $8.55 = 5.15 + 3.4\cos(a+b)$ So $\cos(a+b) = 1$ giving $a + b = 0$	**B1** **[1]**	**3.3**	Correctly relating high tide, *t* = 1 and cos 0	Accept 8.55 or $\cos t = 1$ as evidence of high tide
14	(b)	(ii)	Minimum when $(at+b) = 180°$ and $t = 7\frac{1}{3}$ So $\frac{22}{3}a + b = 180$	**B1** **[1]**	**3.3**	Condone the use 7.2 hours here	Allow for $1.75 = 5.15 + 3.4\cos\left(\frac{22}{3}a + b\right)$
14	(b)	(iii)	Solve simultaneously to give a = 28.42 to 2 dp	**M1** **A1** **[2]**	**3.3** **3.3**	Attempt to solve simultaneous equations: may be **BC** **AG** (value of *b* not needed here)	[$b = -28.42$]
14	(c)		Substitute $h = 3$ $3 = 5.15 + 3.4\cos(28.4t - 28.4)$ $\cos(28.4t - 28.4) = -\frac{43}{68}$ $28.4t - 28.4 = 129.2,\quad 230.8$ $t = 5.55,\quad 9.13$ He does not sail between 5.33 am and 9.08 am	**M1** **A1** **A1** **[3]**	**3.4** **3.4** **3.2a**	Attempting to solve trig equation or inequality At least one correct [decimal] value for *t* Both times correct. Need not convert to hours and minutes. Must indicate between these times	

Question			Answer	Marks	AOs		Guidance
14	(d)		EITHER The model predicts every high tide 8.55 m. The next high tide 8.91 is higher than that so not perfect model.	**B1** **E1** **[2]**	**3.4** **3.5b**	Allow for a comment about the maximum height being wrong. FT their values	
			OR Time difference between high tide and low tide is 6 hr 20 minutes, and between low tide and the next high tide is 5 hours and 40 minutes. The model gives these times as equal, so not perfect model	**B1** **E1** **[2]**		Allow for a comment that the time of the next high tide is wrong. FT their values	
			OR tide reaches 8.91 m when $\cos(at+b)=1.105$ which is impossible	**B1** **E1** **[2]**		Allow for a comment that the height predicted cannot reach 8.91 m. FT their values	
			OR When $t=12.983$ $h=8.35$ which is less than the given value of 8.91 m so the model in not suitable	**B1** **E1** **[2]**		Allow for a comment that the height predicted is not 8.91 m. FT their values	Allow for t = 13 but not $t=12.59$

Question			Answer	Marks	AOs		Guidance
15	(a)		$\mathbf{W} = (-mg\sin 30°)\mathbf{i} + (-mg\cos 30°)\mathbf{j}$ $\left[\mathbf{W} = \left(-\frac{1}{2}mg\right)\mathbf{i} + \left(-\frac{\sqrt{3}}{2}mg\right)\mathbf{j}\right]$	M1 A1 [2]	3.1b 2.5	Attempting to resolve the weight. Allow sin/cos interchange and sign errors for the method mark. All correct in this vector form	*mg* must be seen for the method mark.
15	(b)		$\mathbf{W} + \mathbf{R} + \mathbf{F} = \mathbf{0}$	B1 [1]	2.5	Allow any rearrangement of this. Allow if their expression for **W** is used instead of **W**	
15	(c)		$\mathbf{R} = R\mathbf{j}$ $\left[(-mg\sin 30°)\mathbf{i} + (-mg\cos 30°)\mathbf{j} + (6\mathbf{i} + 8\mathbf{j}) + R\mathbf{j} = \mathbf{0}\right]$ **i** component $-mg\sin 30° + 6 = 0$ giving $m = 1.22$ to 3 sf **j** component: $-12\cos 30 + 8 + R = 0$ $R = 2.39$ so magnitude is 2.39 N	B1 M1 A1 A1 M1 A1 [6]	3.1b 3.1a 1.1 1.1 3.1a 3.2a	Allow for any clear indication that **R** is a multiple of **j** or that it has no component in the **i** direction Forming equation from their **i** terms, or equivalent by resolving parallel to the plane. FT their **W** Correct equation in **i** direction **AG** Equation from the **j** terms (must include all three terms), oe, and using value of *m* Accept arwt 2.4	May be implied with an equation for the i direction with two terms and an equation in the j direction with three terms 12 is the value for *mg*. $1.22\times 9.8 = 11.956$

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