Cambridge Technicals

Engineering

Unit 23: Applied mathematics for engineering

Level 3 Cambridge Technical Certificate/Diploma in Engineering
05823 - 05825 & 05873

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.

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 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.

YOU MUST MARK 5 PRACTICE AND 10 STANDARDISATION RESPONSES BEFORE YOU CAN BE APPROVED TO MARK LIVE SCRIPTS.

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 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, *RM Assessor* messaging or by email.

5. **Crossed Out Responses**
   Where a candidate has crossed out a response and provided a clear alternative then the crossed out response is not marked. Where no alternative response has been provided, examiners may give candidates the benefit of the doubt and mark the crossed out response where legible.

Multiple Choice Question Responses
When a multiple choice question has only a single, correct response and a candidate provides two responses (even if one of these responses is correct), then no mark should be awarded (as it is not possible to determine which was the first response selected by the candidate).
When a question requires candidates to select more than one option/multiple options, then local marking arrangements need to ensure consistency of approach.

Contradictory Responses
When a candidate provides contradictory responses, then no mark should be awarded, even if one of the answers is correct.

Short Answer Questions (requiring only a list by way of a response, usually worth only **one mark per response**)
Where candidates are required to provide a set number of short answer responses then only the set number of responses should be marked. The response space should be marked from left to right on each line and then line by line until the required number of responses have been considered. The remaining responses should not then be marked. Examiners will have to apply judgement as to whether a 'second response' on a line is a development of the 'first response', rather than a separate, discrete response. (The underlying assumption is that the candidate is attempting to hedge their bets and therefore getting undue benefit rather than engaging with the question and giving the most relevant/correct responses.)

Short Answer Questions (requiring a more developed response, worth **two or more marks**)
If the candidates are required to provide a description of, say, three items or factors and four items or factors are provided, then mark on a similar basis – that is downwards (as it is unlikely in this situation that a candidate will provide more than one response in each section of the response space.)

Longer Answer Questions (requiring a developed response)
Where candidates have provided two (or more) responses to a medium or high tariff question which only required a single (developed) response and not crossed out the first response, then only the first response should be marked. Examiners will need to apply professional judgement as to whether the second (or a subsequent) response is a 'new start' or simply a poorly expressed continuation of the first response.

6. Always check the pages (and additional lined pages if present) at the end of the response in case any answers have been continued there. If the candidate has continued an answer there then add an annotation to confirm that the work has been seen.

7. Award No Response (NR) if:
   - there is nothing written in the answer space

   Award Zero '0' if:
   - anything is written in the answer space and is not worthy of credit (this includes text and symbols).

8. The RM Assessor **comments box** is used by your team leader to explain the marking of the practice responses.
Please refer to these comments when checking your practice responses. **Do not use the comments box for any other reason.**
If you have any questions or comments for your team leader, use the phone, the RM Assessor messaging system, or e-mail.

9. Assistant Examiners will email a brief report on the performance of candidates to your Team Leader (Supervisor) by the end of the marking period. Your report should contain notes on particular strength displayed as well as common errors or weaknesses. Constructive criticism of the question paper/mark scheme is also appreciated.

10. **Annotations**

Annotation	Meaning
	Correct response
	Incorrect response
	Missing something
	Benefit of doubt
	Follow through
	Ignore subsequent working
	Method mark awarded 0
	Method mark awarded 1
	Accuracy mark awarded 0
	Accuracy mark awarded 1
	Independent mark awarded 0
	Independent mark awarded 1
	Special case

Mark scheme abbreviations

Other abbreviations in mark scheme	Meaning
oe	Or equivalent
Soi	Seen or implied
www	Without wrong working
ecf	Error carried forward
DM	Method mark dependent on previous M mark

11. **Subject-specific marking instructions**

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. These annotations must be in the body of the work and **not** anywhere near the right hand margin of each page.

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, award marks according to the spirit of the basic scheme; if you are in any doubt whatsoever (especially if several marks or candidates are involved) you should contact your Team Leader.

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.

DM
A method mark which is dependent on a previous method mark.

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.

Unless otherwise indicated, marks once gained cannot subsequently be lost, eg 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.

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. 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.

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, exactly what is acceptable will be detailed in the mark scheme rationale. If this is not the case please consult your Team Leader.

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.

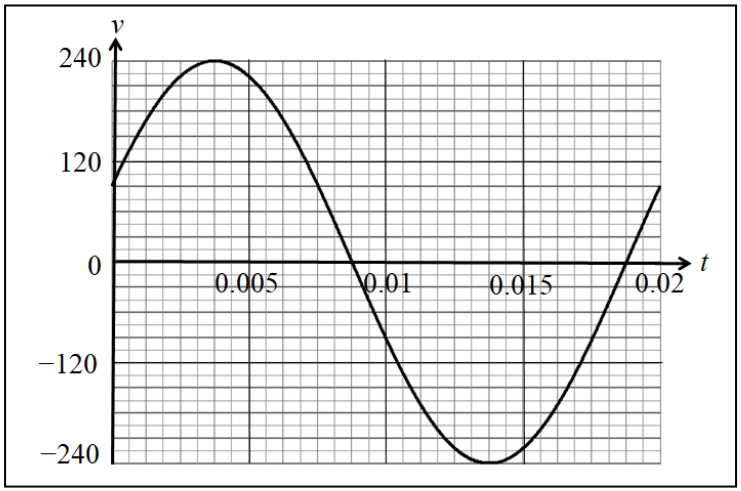
Wrong or missing units in an answer should not lead to the loss of a mark unless the scheme specifically indicates otherwise. Candidates are expected to give numerical answers to an appropriate degree of accuracy, with 3 significant figures often being the norm. Small variations in the degree of accuracy to which an answer is given (e.g. 2 or 4 significant figures where 3 is expected) should not normally be penalised, while answers which are grossly over- or under-specified should normally result in the loss of a mark. The situation regarding any particular cases where the accuracy of the answer may be a marking issue should be detailed in the mark scheme rationale. If in doubt, contact your Team Leader.

Question			Answer	Mark	Guidance
1	(a)		$24 - 4I_1 - 2I_2 = = 0$ $10 + 2I_2 - 5I_3 = 0$	M1	Use $R_1 = 4, R_2 = 2, R_3 = 5$ in both equations
			$24 - (I_2 + I_3)R_1 - I_2R_2 = 0$	B1	I_1 correctly substituted into first equation soi at any stage
			Obtain $6I_2 + 4I_3 = 24$ oe $-2I_2 + 5I_3 = 10$ oe	A1	Both equations, any equivalent 3 term form
				[3]	
1	(b)		$6I_2 + 4I_3 = 24$ $-2I_2 + 5I_3 = 10$		Both method marks can be earned using *their* two 3-term linear equations from 1a
			eg $19I_3 = 54$	M1	Eliminate or substitute to obtain equation in one variable only
			$\rightarrow \quad I_3 = \frac{54}{19}$ or awrt 2.8	A1	Correct value, for I_2 or I_3
			eg $6I_2 + 4\left(\frac{54}{19}\right) = 24 \quad \rightarrow \quad I_2 = \ldots$	M1	Substitute and obtain *their* other value, of I_3 or I_2
			$\rightarrow \quad I_2 = \frac{40}{19}$ or awrt 2.1	A1	Accept correct answers from efficient use of calculator Accept matrices methods for solution of linear equations
				[4]	
1	(c)		$I_1 = \frac{40}{19} + \frac{54}{19} = \frac{94}{19} \quad (= 4.947)$	M1	Obtains *their* I_1 by using their $I_2 + I_3$ from 1b soi
			$P = \left(\frac{94}{19}\right)^2 4 + \left(\frac{40}{19}\right)^2 2 + \left(\frac{54}{19}\right)^2 5$	M1	Use of total power = $I_1^2 R_1 + I_2^2 R_2 + I_3^2 R_3$, with all three contributions required (P = 97.9058 + 8.8642+40.3878)
			=147 (W)	A1	Exact value $\frac{2796}{19}$ or awrt to 150
				[3]	
				10	

Question			Answer	Mark	Guidance
2	(a)				Accept any valid method and order of evaluation
			$\boldsymbol{c = 12}$	**B1**	Sight of **c=12** (from point A: $x = 0, y = 12$) OR embedded in: $y = ax^2 + bx + \mathbf{12}$
			B: $x = 30, y = 15$ $\rightarrow \ 15 = a(30)^2 + b(30) + 12$	**M1**	Use point B in given equation (c may still be present)
			$\left(\frac{dy}{dx} =\right) \ 2ax + b$	**B1**	Correct derivative seen or implied
			E: $x = 20, \frac{dy}{dx} = 0 \quad \rightarrow \ 2a(20) + b = 0$	**M1**	Use gradient is zero at point E to obtain linear equation Note: $20 = -\frac{b}{2a}$ seen scores B1M1
					Expect equations: $15 = 900a + 30b + 12 \ \ oe$ and $0 = 40a + b$ oe
			$\boldsymbol{a}$ **= – 0.01** oe $\boldsymbol{b}$ **= 0.4** oe (c = 12)	**A1**	Solve correct equations to obtain a, b
				[5]	

Question			Answer	Mark	Guidance
2	(b)		$\frac{dy}{dx} = 2(-0.01)15 + 0.4 \quad \left(\rightarrow \quad \frac{dy}{dx} = 0.1\right)$	M1	Use x coordinate of point C $(x = 15)$ in attempt at gradient of tangent at C, using *their* a and b in $2ax + b$
			$m_{CD} = -\frac{1}{0.1} = -10$	M1	Evaluates gradient of CD, using negative reciprocal of *their* tangent gradient
			$y_C = -0.01(15^2) + 0.4(15) + 12 = \frac{63}{4}$ or 15.75		
			Line CD: $y - 15.75 = -10(x - 15)$ oe	M1	Use $x = 15$ with *their* a, b, c from 2a to find height of point C, and form equation of line CD
			y = −10 *x* + 165.75	A1	Correct 3-term equation of roof support CD Any equivalent form, eg $10x + y = \frac{663}{4}$
				[4]	
2	(c)		AB: $y = 0.1x + 12$ oe	B1	Equation of joist AB, soi in this part
			Solve simultaneous equations CD: y = −10 *x* + 165.75 oe AB: $y = 0.1x + 12$ oe $\rightarrow \quad x = \ldots$ OR $\rightarrow \quad y = \ldots$	M1	Solve correct equations of CD and AB simultaneously to find x or y. Note: $y = \frac{12+15}{2} (= 13.5)$ is M0A0
			Height of point D = 13.52 (m)	A1	Obtain correct height of point D with sight of 13.52 or $\frac{5463}{404}$ or better. Note $x = 15.22$ or $\frac{3075}{202}$ Accept correct answers from efficient use of calculator
				[3]	
				12	

Question			Answer	Mark	Guidance
3	(a)		$1146 \times 2\pi \div 60$ (=120.0088) oe	M1	Convert rpm to rad/s $\left(\frac{191}{5\pi}\right)$ OR circumference is $2\pi(0.05) = 0.1\pi = 0.314$m
			$\mathbf{V_{AO}} \approx 120.0088 \times 0.05 \approx 6$ (m/s) **AG**	A1	Correctly show that speed is approx 6, with evidence of rounding seen, which might occur at an intermediate stage or at the end. OR $\frac{1146}{60} = 19.1 \rightarrow \ 0.314 \times 19.1 \approx 6$
				[2]	
3	(b)				Accept valid alternative methods
			$\sin\alpha\ /50 = \sin\theta/150$	M1	Sine rule with appropriate angles and sides
			sin(α)=50sin((30)/150	M1	sin(α) as the subject oe
			α = 9.59	A1	Correct answer awrt 9.6. Accept answer in radians
				[3]	
3	(c)	(i)	X = 60	B1	
				[1]	
3	(c)	(ii)	Y= 80.4	B1	(80.406) B1FT $90 -$ *their* α from 3b
				[1]	
3	(c)	(iii)	Z= 39.6	B1	(39.59) B1FT $30 +$ *their* α from 3b
				[1]	
3	(d)		$6/\sin(80.4) = VB_O/\sin(39.6)$	M1	Application of sine rule using *their* Y and Z
			$VB_O = 3.9$ (3.8786) (m s^{-1})	A1	Awrt 3.9
				[2]	
				10	

Question			Answer	Mark	Guidance
4	(a)			**B1** **B1** **B1** **B1**	Correct labels and appropriate scales with a range that includes -240 and 240 Single period of sine curve Correct amplitude Sine curve shifted to left by a reasonable small amount
				[4]	
4	(b)		$\cos(A+B) = \cos A\cos B - \sin A\sin B$ $\cos(A-B) = \cos A\cos B + \sin A\sin B$	**B1**	Both correct formulas, seen explicitly
			$cos\,A\,cos\,B + sinAsinB - (cos\,A\,cos\,B - sin\,A\,sin\,B)$	**M1**	Subtraction seen
			$= 2\,sin\,A\,sin\,B$		
			$sin\,A\,sin\,B = \frac{1}{2}[cos(A-B) - cos(A+B)]$ **AG**	**A1**	Obtain given result convincingly, with at least one intermediate step
				[3]	

Question			Answer	Mark	Guidance
4	(c)				Note: may be using 100π for ω first 4 marks
			$P = 240\sin\left(\omega t + \frac{\pi}{8}\right) \times 4\sin\left(\omega t + \frac{3\pi}{8}\right)$	**B1**	Forms P correctly as $v \times i$
			$A - B$: $-\frac{2\pi}{8}$ $A + B$: $2\omega t + \frac{4\pi}{8}$	**B1**	Compares with identity from 4b, to correctly obtain angles $A - B$ and $A + B$. Allow unsimplified here.
			$P = 960\left(\frac{1}{2}\right)\left[\cos\left(-\frac{2\pi}{8}\right) - \cos\left(2\omega t + \frac{4\pi}{8}\right)\right]$	**M1**	Substitution into identity from 4b with *their* attempt at $A - B$ and $A + B$. Allow unsimplified here.
			$P = 480\left[\left(\frac{\sqrt{2}}{2} - cos(2\omega t + \frac{\pi}{2})\right)\right]$	**M1**	For sight of: $2\omega t + \frac{\pi}{2}$ before final simplification
			$P = 480(\frac{1}{\sqrt{2}} + sin(2\omega t))$ (W) **AG**	**A1**	Obtain given result convincingly
				[5]	
4	**Total**			**12**	

Question			Answer	Mark	Guidance
5	(a)		Volume of steel: $V = \frac{4}{3}\pi\,(1^3 - (1-0.05)^3)$ $(= 0.5974)$ Mass of steel: $M = \frac{4}{3}\pi(1 - 0.95^3) \times 8000$ = 4779.41 (kg)	**M1** **M1** **A1**	Attempts volume, using correct formula for volume of sphere, and radii of 1 and 0.95 Attempts mass using density of steel as 8000 and *their* volume Exact value $\frac{4564}{3}\pi$ or 4800 or better
				[3]	
5	(b)		Mass of water displaced by totally submerged ball = 4188.7 kg Since 4779.41 > 4188.7 the ball will sink	**B1** **B1FT**	Accept 4190 or better FT their mass of steel ball from 5a, compared to correct mass of displaced water (4190 or better), with appropriate conclusion
				[2]	

Question			Answer	Mark	Guidance
5	(c)		$\frac{2x^2}{2} - \frac{x^3}{3}$	M1 A1	Integrate to obtain either term Integration correct (with or without +c)
			$0.5^2 - \frac{0.5^3}{3}$	DM1	For applying limits to *their* integrated function, in correct order. Implied by sight of $\frac{5}{24}$ or 0.208
			$M_w = 1000\pi\left(0.5^2 - \frac{0.5^3}{3}\right) = 654.49\ (kg)$	A1	Exact value $\frac{625}{3}\pi$ or awrt 650. Allow efficient use of calculator throughout
				[4]	
5	(d)		$\frac{4}{3}\pi(1-(1-t)^3)$	B1	Expression for volume of steel with wall thickness t
			$8000 \times \frac{4}{3}\pi(1-(1-t)^3) = 654.49$ $\rightarrow \quad (1-(1-t)^3) = \frac{5}{256} = 0.019531$	M1	Equate masses following correct expression for volume of steel, and attempt to solve for t.
			t = 0.00655 (m) oe	A1	Awrt 0.007(m) or 7mm Allow efficient use of calculator throughout
				[3]	
5	Total			12	

Question			Answer	Mark	Guidance
6	(a)		$\frac{dT}{dt} = 9t\left(-\frac{1}{3}e^{-\frac{t}{3}}\right) + e^{-\frac{t}{3}}(9)$ oe	M1	Differentiate using the product rule, 2 separate terms with v' of form $ke^{-\frac{t}{3}}$ where $k = \pm\frac{1}{3}$ or ± 3 and u'as 9 oe
				A1	Correct derivative
			$9t\left(-\frac{1}{3}e^{-\frac{t}{3}}\right) + e^{-\frac{t}{3}}(9) = 0$ $e^{-\frac{t}{3}}(-3t + 9) = 0$ $\rightarrow \quad t = 3$	DM1	Set derivative to zero, and correct process for solving to t =
			Time of day 7am + 3 = 10 am	A1	Correct time of day found
			Test for maximum or minimum: $\frac{d^2T}{d^2t} = e^{-\frac{t}{3}}(t - 6)$ oe when t = 3 $\rightarrow$ $= -3e^{-1}$ (-1.1036) oe $-3e^{-1} < 0$ therefore maximum	B1	Correct process for verifying that t=3 is a maximum eg 2nd derivative evaluated, or gradient test either side of t =3
			eg t = 1 $\rightarrow$ T = 21.4 t = 2 $\rightarrow$ T = 24.2 **t = 3 $\rightarrow$ T = 24.9** t = 4 $\rightarrow$ T = 24.5	M1 A1	**Alternative Numerical Method** Evaluates temperature for at least 3 different values of t Correct temperature when t = 3
			Time of day 7am + 3 = 10 am	A1	Correct time of day found
			eg t = 2.5 $\rightarrow$ T = 24.8 and t = 3.5 $\rightarrow$ T = 24.8	M1	Evaluates temperatures either side of t=3 (interval 3 ± 0.5)
			eg t = 2.985 $\rightarrow$ T = 24.9326 t = 3.015 $\rightarrow$ T = 24.9326 with t= 3$\rightarrow$ T = 24.9327 therefore maximum	A1	Evaluates temperatures either side of t = 3, in the interval $t = 3 \pm \frac{1}{60}$ to show that this is a local maximum
				[5]	

Question			Answer	Mark	Guidance
6	(b)		$\frac{1}{10-0}\int_0^{10} 9te^{-\frac{t}{3}} + 15\,dt$		
				B1	Correct substitution of x_0, x_1 into given equation Allow in terms of x rather than t
			$u = 9t \qquad v' = e^{-\frac{t}{3}}$ oe $u' = 9 \qquad v = -3e^{-\frac{t}{3}}$ oe	M1	Attempt integration by parts, soi by u, v', and attempt at u', v with v of form $ke^{-\frac{t}{3}}$ where $k = \pm 3$ or $\pm\frac{1}{3}$
			$\int 9t\,e^{-\frac{t}{3}}\,dt = (9t)\left(-3e^{-\frac{t}{3}}\right) - \int(-3e^{-\frac{t}{3}})(9)\,dt$		
			$= -27te^{-\frac{t}{3}} - 81e^{-\frac{t}{3}}$ oe	DM1	Complete attempt at integration by parts, dependent on M1
				A1	Fully correct integration of $9te^{-\frac{t}{3}}$ oe soi
			$\frac{1}{10}\left[-27te^{-\frac{t}{3}} - 81e^{-\frac{t}{3}} + 15t\right]_0^{10}$		
				DM1	Apply limits correctly, following earlier M1M1, and with 15t present
			$\approx 21.8478\ (^oC)$	A1	Awrt 22 Allow efficient use of calculator throughout
				[6]	
6	Total			11	

Question			Answer	Mark	Guidance
7	(a)		$t^2 + 7t + 10 \rightarrow (t+2)(t+5)$ $\frac{15t+66}{(t+2)(t+5)} = \frac{A}{t+2} + \frac{B}{t+5}$ $15t + 66 = A(t+5) + B(t+2)$ eg $t = -5$: $-75 + 66 = -3B \quad \rightarrow B = 3$ OR $t = -2$: $-30 + 66 = 3A \quad \rightarrow A = 12$ A = 12 and B = 3	**B1** **M1** **DM1** **A1**	Factorise denominator correctly Form partial fractions, and clear the denominator oe soi Correct process to obtain A or B soi Oe eg set up and solve $A + B = 15$, $5A + 2B = 66$ Both correct
				[4]	
7	(b)		$v = 12\,ln(t+2) + 3\,ln(t+5) \quad (+c)$ $t = 0, v = 0 \rightarrow \quad c = -12\,ln\,2 - 3\,ln\,5 \quad oe$ $v = 12\,ln(t+2) + 3\,ln(t+5) - 12\,ln\,2 - 3\,ln\,5$	**M1** **A1FT** **M1** **A1**	Integrate *their* answer to 7a to obtain log terms Both terms correct (+c), **FT** *their* A and B from 7a Evaluate *their* c, if correct may see -13.15 or $-\ln 512000$ Final integral aef
				[4]	

Question			Answer	Mark	Guidance
7	(c)		$a \approx 1.034$ (m s^{-2})	B1	Correct acceleration 1.03 or better www Or exact value $\frac{123}{119}$
				[1]	
7	(d)		$v = 12\,ln(12+2) + 3\,ln(12+5) - 13.15$ $v \approx 27.02$ (m s^{-1})	M1 A1	Substitute t = 12 into *their* v from 7b soi Correct speed 27 or better www
				[2]	
7	(e)		40=27.02 +1.034 t t = (40-27.02)/1.034 $= \frac{40}{27.02} + \frac{0.1034}{}$ ≈ 12.55 (s)	M1 A1	Find time using correct constant acceleration equation(s) with *their* a from 7c and *their* v from 7d, where *their* $v < 40$ Final answer as decimal, awrt 12.5 or 12.6
				[2]	
7	Total			13	

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