Cambridge Technicals
Engineering

Unit 23: Applied mathematics for engineering

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

Mark Scheme for January 2024

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It is also responsible for developing new specifications to meet national requirements and the needs of students and teachers. OCR is a not-for-profit organisation; any surplus made is invested back into the establishment to help towards the development of qualifications and support, which keep pace with the changing needs of today's society.

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 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 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. **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).

Team Leaders must confirm the correct use of the NR button with their markers before live marking commences and should check this when reviewing scripts.

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
	Follow through
	Benefit of doubt
	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.

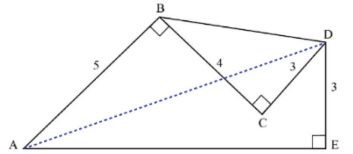
Unless otherwise indicated, marks once gained cannot subsequently be lost, eg wrong working following a correct form of answer is ignored. Sometimes this is reinforced in the mark scheme by the abbreviation isw. However, this would not apply to a case where a candidate passes through the correct answer 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	Marks	Guidance
1	(i)		$[BD^2=4^2+3^2]$ [BD=] 5 (m)	B1	Accept 5 without working
				[1]	
1	(ii)		$C\hat{B}D$ = $\tan^{-1}(3/4)$ oe	M1	Or for $B\hat{D}C = \tan^{-1}\frac{4}{3}$ oe
			= 36.9° [36.87]	A1	Must be angle CBD now. Allow in radians (0.64) here
			$A\hat{B}D$ = 90+36.9 = 126.87° or 126.9 **AG**	B1	Obtains AG with evidence of correct method Note: 180-53.1 = 126.9 scores A0B0 unless fully justified with clear ref to AB parallel to CD extended
				[3]	
1	(iii)		$AD^2 = 5^2 + (\text{BD})^2 - 2(5)(\text{BD})\cos 126.9$ or $\frac{5}{\sin 26.55} = \frac{AD}{\sin 126.9}$	M1	Cosine rule or sin rule used correctly in ΔABD
			AD = 8.9(44)	A1	$\sqrt{80}$ or $\sqrt{80.02}$, awrt 8.94 or 8.95 soi
			ALT using isosceles triangle ABD: BD must be 5 in (i) $\frac{1}{2}AD = 5\cos((180\text{-}126.9)/2)$ [=4.4721] AD=8.9442.. awrt 8.94 or 8.95 soi	M1 A1	
			$AE^2=AD^2-3^2$	M1	With their AD from a trig calculation
			AE=8.4(261) (m) [or $\sqrt{71}$]	A1	awrt 8.4
				[4]	
1	(iv)		$B\hat{A}D = 26.565$	B1	soi in this part, any accuracy
			$D\hat{A}E = \tan^{-1}\left(\frac{3}{AE}\right)$	M1	oe eg $D\hat{A}E = \sin^{-1}\left(\frac{3}{AD}\right)$ Note: $D\hat{A}E \approx 19.6$
			$BF = 5\sin(B\hat{A}F)$ BF = 3.6(065) (m)	M1 A1	soi where $B\hat{A}F$ is the sum of their two calculated angles awrt 3.6 Note: use of 45° → 3.53 scores M0M0A0 max 1/4
				[4]	
				12	

Question			Answer	Marks	Guidance
2	(i)		$C_2 + C_3 + C_2C_3 = 3(C_2 + C_3)$ $C_2(C_3 - 2) = 2C_3$ $C_2 = \frac{2C_3}{C_3 - 2}$ **AG**	**M1** **A1**	Correct method to clear the fraction. Note: if the 3 and 1 are combined first → $C_2C_3 = 2(C_2 + C_3)$ Obtain given answer, with evidence of collecting C_2 terms and factorising
				[2]	
2	(ii)		$\frac{\frac{2C_3}{C_3 - 2}}{\frac{2C_3}{C_3 - 2} + 1} + C_3 = 6.75$ $\left[\frac{2C_3}{C_3 - 2} + 1 = \frac{2C_3 + C_3 - 2}{C_3 - 2} =\right] \frac{3C_3 - 2}{C_3 - 2}$ $\frac{2C_3}{(C_3 - 2)} + C_3\left(\frac{3C_3 - 2}{C_3 - 2}\right) = 6.75\left(\frac{3C_3 - 2}{C_3 - 2}\right)$ $2C_3 + C_3(3C_3 - 2) = 6.75(3C_3 - 2)$ $3C_3^2 - 20.25C_3 + 13.5 = 0$ **AG**	**M1** **B1** **M1** **A1**	Substitute 2i in attempt to obtain equation in C_3 only Correct simplified expression for $C_2 + 1$ in terms of C_3 soi Correct method to clear all fractions and obtain quadratic in C_3 www
				[4]	

Question			Answer	Marks	Guidance
2	(iii)		$C_3 = \frac{20.25 \pm \sqrt{(-20.25)^2 - 4 \times 3 \times 13.5}}{2 \times 3}$	M1	Appropriate method leading to two roots, implied by sight of both correct values
			$C_3 = 6$, $C_3 = 0.75$	A1	Both required although 0.75 might be immediately rejected
			$C_2 = \frac{2\times6}{6-2} = 3 \quad \left[C_2 = \frac{2\times0.75}{0.75-2} = -1.2\right]$	DM1	Substitutes at least one value obtained from solving a quadratic into appropriate expression for $C_2 =$
			$C_3 = 6, C_2 = 3$ only	A1	Must be clear that these are the only final values
				[4]	
				10	

Question			Answer	Marks	Guidance
3	(i)		[Midpoint of AB =] (4,7)	B1	
				[1]	
3	(ii)		[Midpoint of BC =] (12,11)	B1	
				[1]	
3	(iii)		$\frac{10-7}{18-4}$ $\left[=\frac{3}{14}\right]$ $(y-7)=\frac{3}{14}(x-4)$ $14y-98=3x-12$ $3x-14y=-86$ **AG**	M1 A1	Calculation of required gradient soi Uses gradient with either point in a complete method to find the correct equation ALT: B1for correctly testing correct midpoint of AB **and** vertex C in given equation. B1 for convincing explanation that centroid will also lie on this line
				[2]	
3	(iv)		eg median from A: $\frac{11-2}{12-2}$ $\left[=\frac{9}{10}\right]$ $(y-2)=\frac{9}{10}(x-2)$ $10y-20=9x-18$ $9x-10y=-2$	M1 A1	Note: accept use of either remaining median here Calculation of required gradient soi Uses gradient with either point in a complete method to find a correct 3 term equation Allow any equivalent 3 term form
				[2]	

Question			Answer	Marks	Guidance
3	(v)				Non-matrix methods cannot score here. Must be bringing forward a 2nd distinct equation from 3iv
			Det $\begin{bmatrix}3 & -14\\9 & -10\end{bmatrix} = -30 + 126 = 96$	B1ft	Their determinant soi
			$\begin{bmatrix}-10 & 14\\-9 & 3\end{bmatrix}$	M1	Forms the adjoint of *their* matrix
			$\begin{bmatrix}x\\y\end{bmatrix} = \begin{bmatrix}3 & -14\\9 & -10\end{bmatrix}^{-1}\begin{bmatrix}-86\\-2\end{bmatrix}$ or $\begin{bmatrix}x\\y\end{bmatrix} = \frac{1}{96}\begin{bmatrix}-10 & 14\\-9 & 3\end{bmatrix}\begin{bmatrix}-86\\-2\end{bmatrix}$	M1 A1	Uses $AA^{-1} = I$ to write an appropriate equation Correct equation
			$\frac{1}{96}\begin{bmatrix}832\\768\end{bmatrix} \quad \rightarrow \quad x = \frac{26}{3} \quad y = 8$	A1	x and y both correct. Allow in matrix form.
				[5]	
				11	

Question			Answer	Marks	Guidance
4	(i)		$\left[f = \frac{1}{T} = \frac{1}{0.4} =\right]$ 2.5 Hz	B1 B1	 Must state units. Accept cycles per second
				[2]	
4	(ii)		$[0 = Ae^{-0.2a}\sin 0.2b \rightarrow]$ $0 = \sin 0.2b$ $[0.2b = \pi \rightarrow]$ $b = 5\pi$	M1 A1	 Allow 15.7 Allow b $= 900$ if working in degrees
			ALT Using $\omega = 2\pi f$: $2\pi \times 2.5$ $b = 5\pi$	M1 A1	 Allow 15.7
				[2]	
4	(iii)		$Ae^{-0.1a}\sin(5\pi \times 0.1) = 120$ $Ae^{-0.3a}\sin(5\pi \times 0.3) = -60$	B1ft	Both soi. Using t=0.1 and t=0.3 and their value of b from ii. Sight of $Ae^{-0.1a} = 120$ **and** $Ae^{-0.3a} = 60$ implies B1
			$\frac{Ae^{-0.1a}}{Ae^{-0.3a}} = \frac{120}{60}$	M1	Method to eliminate A
			$e^{0.2a} = 2$ $0.2a = \ln 2$	M1	Solve using logs
			$a = \left(\frac{\ln 2}{0.2} =\right) 5\ln 2$	A1	anything which rounds to 3.5
				[4]	
4	(iv)		$[120 = Ae^{-0.1a}$ or $-60 = -Ae^{-0.3a}]$		
			$A = \frac{120}{e^{-0.1a}}$ or $A = \frac{60}{e^{-0.3a}}$	M1	Rearrange either equation to obtain expression for A Note: equations may use their b with $t = 0.1$ or 0.3
			$A = \frac{120}{e^{-0.1(5\ln 2)}}$ or $A = \frac{60}{e^{-0.3(5\ln 2)}}$	M1	Substitute their a into either equation
			$A = 170$	A1	Note: exact value is $120\sqrt{2} = 169.7$
				[3]	

Question			Answer	Marks	Guidance
4	(v)				Method marks available with/without values for a and b
			$\frac{dy}{dt} = A(e^{-at}b\cos b\,t - ae^{-at}\sin b\,t)$	M1	Attempt at product rule of form $uv' + vu'$
			$Ae^{-at}(b\cos b\,t - a\sin b\,t) = 0$	DM1	Sets their derivative = 0
			$b\cos b\,t = a\sin b\,t$		
			$\frac{b}{a} = \tan b\,t$	DM1	Form expression for tan
			$t = \frac{1}{b}\tan^{-1}\frac{b}{a} = 0.086$	A1	Anything which rounds to 0.09
				[4]	
				15	

Question			Answer	Marks	Guidance
5	(i)		$[\boldsymbol{d} =] \pm \left((2t-1)\boldsymbol{i} + (10-25t)\boldsymbol{j}\right)$	B1	Displacement vector seen or implied in any equivalent form
			$[d =]\sqrt{(2t-1)^2 + (10-25t)^2}$	M1	
			$d = \left(\sqrt{629t^2 - 504t + 101}\right) \times 50$	A1	Must have factor 50, but can be unsimplified
				[3]	
5	(ii)		eg $\frac{dd}{dt} = \frac{1}{2}\left(\frac{1258t-504}{\sqrt{629t^2-504t+101}}\right)[\times 50]$	M1	Differentiate *their d* and obtain *their* unsimplified correct form. Or differentiate *their* d^2 and obtain *their* unsimplified correct form
				M1	Equate their derivative to zero and solve
			[t= 504/1258 = 0.40063]…= 0.40 (hours) (2dp)	A1	Accept correct decimal answer straight from calculator eg [252/629 →] 0.40 2dp
				[3]	
5	(iii)		eg $d = \left(\sqrt{629(0.4)^2 - 504(0.4) + 101}\right)[\times 50]$	M1	Substitute their t <u>from ii</u> into their expression for d <u>from i</u> or d^2 or $\boldsymbol{d}$ and calculate distance Note: solving correctly for d^2 gives 0.0397 for d^2 rather than d, and does not score yet
			ALT: use their t from ii to determine position of both aircraft and calculate the distance between them	M1	
			Actual separation distance = 0.199 × 50 =10 (km)	A1	
			Safety conditions are satisfied	B1	For B mark factor of 50 must be used Dep on all earlier marks
				[3]	
				9	

Question			Answer	Marks	Guidance
6	(i)				$V = \int_0^{100} \pi(5\cos\frac{x\pi}{100} + 25)^2 dx$
			$25\cos^2\frac{x\pi}{100} + 250\cos\frac{x\pi}{100} + 625$	M1	Square the bracket to obtain 3 terms of correct form
			$25 \times \mathbf{\frac{1}{2}\left(\cos\frac{2x\pi}{100} + 1\right)} + 250\cos\frac{x\pi}{100} + 625$	M1	Substitute the given trig identity
			$V = 25\pi\int_0^{100}\frac{1}{2}(\cos\frac{x\pi}{50} + 1) + 10\cos(\frac{x\pi}{100}) + 25 \ \ dx$	A1	Obtain correct integrand
			$V = 25\pi\left[\frac{1}{2}\left(\frac{50}{\pi}\right)\sin\frac{x\pi}{50} + \frac{x}{2} + 10\left(\frac{100}{\pi}\right)\sin\frac{x\pi}{100} + 25x\right]_0^{100}$	M1 A1	Integrate $[k]\cos Ax \rightarrow \left[\frac{k}{A}\right]\sin Ax$ Integration fully correct
			$V = 25\pi\left[\left(\frac{25}{\pi}\sin 2\pi + \frac{100}{2} + \frac{1000}{\pi}\sin\pi + 2500\right) - 0\right]$ $V = 25\pi\left[\left(\frac{100}{2} + 2500\right)\right]$	M1	Use upper limit (and zero) appropriately Note: sight of 282696(.12) implies first 6 marks
			$V = 200276.5\ldots(\text{mm}^3)$	A1	Note: exact answer is 63750π and sight of this implies first 7 marks
			$V \approx 2 \times 10^{-4}(m^3)$	B1ft	Convert their answer into correct units
				[8]	

Question			Answer	Marks	Guidance
6	(ii)		At the large end $\pi 0.03^2 \times 0.5\ \text{m}^3 s^{-1}$	M1	Allow any units for method marks Area of either end soi
			At the small end $\pi 0.02^2 \times v\ \text{m}^3 s^{-1}$	M1	Use of volume flow rate = area × speed soi Note: use of ratio 9:4 to calculate speed implies both marks, but use of ratio 3:2 is M0 M0
			$\pi 0.03^2 0.5 = \pi 0.02^2 \times v$ $v = 1.125\ (\text{ms}^{-1})$	A1	
				[3]	
				11	

Question			Answer	Marks	Guidance
7	(i)		Volume in tank = $\pi \times 0.2^2 \times 0.8$ $[= 0.032\pi]$	B1	Correct volume soi (= 0.1005.. m^3) using any units
			Q = 32π ×4183 ×45 =18923446 J (Ws)	M1	Heat energy calculated using their mass
			$t = \frac{Q}{2500} = 7569(s) = 2.1\ (hr)$	A1	Answer in range 7200-7800, 2hr-2hr10m Without wrongly stated units
				[3]	
7	(ii)		$\int \frac{1}{q - K(T-A)} \mathrm{d}T = \int \frac{1}{cm} \mathrm{d}t$	B1	Separate variables correctly
			$\boldsymbol{\frac{ln(q - K(T-A))}{-K} = \frac{t}{cm} + d}$	M1	Integrate using given result to obtain an appropriate log term with divisor
				A1	Correct log term
			$ln(q - K(T-A)) = -\frac{Kt}{cm} + d'$	B1	RHS correct and including a constant of integration
			$q - K(T-A) = De^{-\frac{Kt}{cm}}$	M1	Appropriate attempt at antilogs
			$t = 0, T = A \ \rightarrow \ D = q$	M1	Attempt expression for their constant of integration using $t = 0, T = A$ Note: these two marks in either order
			$K(T-A) = q - qe^{-\frac{Kt}{cm}}$	DM1	Obtain equation in t, T, A, K, c, m. Dependent on all earlier method marks
				DM1	Attempt to make T the subject. Dependent on all earlier method marks
			$T = A + \frac{q}{K}(1 - e^{-\frac{Kt}{mc}})$	A1	Any equivalent form at every stage and for final answer
				[9]	
				12	

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