# Cambridge Technicals

# Engineering

## Unit 3: Principles of mechanical engineering

Level 3 Cambridge Technical in Engineering
**05822 - 05825 & 05873**

# Mark Scheme for January 2025

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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 available in RM Assessor

3. Log-in to RM Assessor and mark the **required number** of practice responses ("scripts") and the **required number** of 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% 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, email or via the RM Assessor messaging system.

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.

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**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 objects 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 the annotation 'SEEN' to confirm that the work has been seen and mark any responses using the annotations in section 10.

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7. There is a NR (**No Response**) option. Award NR (No Response):

   - if there is nothing written at all in the answer space
   - 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) which is not an attempt at the question.

   Note: Award 0 marks – for an attempt that earns no credit (including copying out the question).

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.**

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

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10. **Annotations**

| Annotation | Meaning |
|---|---|
| | Correct response worthy of a mark. Number of ticks = number of marks awarded. |
| | Incorrect response |
| | Missing something/incomplete response |
| | Error carried forward |
| | Benefit of doubt |
| | No benefit of the doubt |
| | Power of ten error |
| | Rounding error |
| | Significant figure error |
| | Transcription error |
| | Seen |
| | Blank page |

**Mark scheme abbreviations**

| Other abbreviations in mark scheme | Meaning |
|---|---|
| oe | Or equivalent |
| isw | Ignore subsequent working |
| awrt | Answer which rounds to |
| soi | Seen or implied |
| SC | Special case |

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In all numerical calculation questions a correct response to 2 sf will gain all marks unless specified otherwise. When an answer is given to more than 2 sf, if it rounds to the answer given in the mark scheme to 2 sf, the mark can be awarded.

If this is not the case for specific questions, this will be detailed in the mark scheme. You do not need to see all the workings if the answer is correct. Any answers or units in brackets do not need to be seen.

If the data given in a question is to 2 sf, then allow to 2 or more significant figures. If an answer is given to fewer than 2 sf, then penalise once only in the entire paper.

Penalise a rounding error in the second significant figure once only in the paper.

11. **Subject-specific marking instructions**

Full marks can be awarded if the correct answer is seen without any method or with no incorrect working.

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| Question | | | Answer/Indicative content | Mark | Guidance |
|---|---|---|---|---|---|
| 1 | (a) | (i) | (28 x 28) – (24 x 24) = 784 – 576 | 1 | Evidence of calculation for area; two of 784, 576 and subtraction, allow POT error for this mark |
| | | | = 208 ($mm^2$) or 2.08 x $10^{-4}$ ($m^2$) | 1 | isw if conversion is incorrect |
| | | | **Alternative method 1** | | |
| | | | 2 (2 x 28) + 2(2 x 24) = 112 + 96 | 1 | Evidence of calculation for area; two of 112, 96 and addition |
| | | | = 208 ($mm^2$) or 2.08 x $10^{-4}$ ($m^2$) | 1 | isw if conversion is incorrect |
| | | | **Alternative method 2** | | |
| | | | (26 x 2) + (26 x 2) + (26 x 2) + (26 x 2) | 1 | Evidence of calculation for area, allow 104 or 156 |
| | | | = 208 ($mm^2$) or 2.08 x $10^{-4}$ ($m^2$) | 1 | isw if conversion is incorrect |
| | | | | **[2]** | |
| | | (ii) | | | Allow ecf from a (i) throughout |
| | | | Volume = 208 x 750 (= 156000 $mm^3$) | 1 | Evidence of appropriate calculation for volume |
| | | | 156000 $mm^3$ = 0.000156/ 1.56 x $10^{-4}$ $m^3$ | 1 | Conversion of units at any stage of calculations |
| | | | Mass = 7870 x 0.000156 = 1.228 (kg) | 1 | Allow density x *their* volume in $m^3$ i.e. POT error |
| | | | | | If *their* mass or density x volume is multiplied by 9.8(1) at any point then the final mark **CANNOT** be awarded |
| | | | | **[3]** | |

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| Question | | | Answer/Indicative content | Mark | Guidance |
|---|---|---|---|---|---|
| 1 | (b) | (i) | 1250/ 175 = 7.14 (N / $mm^2$) or 7.14 x $10^6$ (Pa) | 1 | Allow 7 (N / $mm^2$) or 7 x $10^6$ (Pa) Unit 2 LO 4.12 |
| | | | | **[1]** | |
| | | (ii) | | | Allow ecf from b (i) throughout |
| | | | 210 x $10^9$ = 7.14 x $10^6$ / strain | 1 | Evidence of use of YM = stress/strain |
| | | | ∴ Strain = (7.14 x $10^6$) /210 x $10^9$ = 3.401 x $10^{-5}$ | | |
| | | | (change in length / (100 x $10^{-3}$) = 3.401 x $10^{-5}$) | | |
| | | | ∴ change in length = 3.401 x $10^{-5}$ x 100 x $10^{-3}$ | 1 | Evidence of use of change in length = strain x length, allow *their* value of strain for this mark only |
| | | | = 3.4 x $10^{-6}$ (m) oe 3.4 x $10^{-3}$ /0.0034 mm | 1 | Need to have correct unit shown for mm or equivalent isw if further conversion is incorrect |
| | | | | **[3]** | |

| Question | | | Answer/Indicative content | Mark | Guidance |
|---|---|---|---|---|---|
| 2 | (a) | (i) | VR = 50/11 (4.55) or 34/11 (3.09) or 50/28 (1.79) or 34/28 (1.21)<br>VR = 50 / 11 = 4.5454…. or 4.545 or 4.55 or 4.5 | 1<br>1 | Use of VR = Input teeth/Output teeth |
| | | | | **[2]** | |
| | | (ii) | Lowest VR 34/28 (=1.2143)<br>80 x (34 / 28) = 97.1428… (rpm) (97.1429) | 1<br>1 | Selection of lowest VR<br>Accept 96 (rpm) (VR = 1.2) or 96.8 (rpm) (VR = 1.21) |
| | | | | **[2]** | |
| | | (iii) | 80 x 50/11 = 363.6363…. (363.6364)<br>363.6364 – 97.1429 = 266.4935 (rpm) | 1<br>1 | Allow ecf from a (i) and a (ii) throughout<br>Evidence of use of appropriate formula.<br>Accept 264 (rpm) to 268 (rpm) depending on rounding in a (ii) |
| | | | **Alternative method**<br>Difference between highest and lowest VR<br>= 50/11 – 34/28 (= 3.3312)<br>80 x 3.3312 = 266.4935 (rpm) | <br><br>1<br>1 | Allow ecf for VR from a (i) and a (ii) throughout<br><br>Evidence of use of appropriate formula.<br>Accept 80 x *their* difference in VR<br>Accept 264 (rpm) to 268 (rpm) depending on rounding in a (ii) |
| | | | | **[2]** | |

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| Question | | | Answer/Indicative content | Mark | Guidance |
|---|---|---|---|---|---|
| 2 | (b) | (i) | $0.75^2\pi$ (= 1.767 $mm^2$) | 1 | Use of area = $\pi r^2$ allow POT error for this mark |
| | | | 270 x 1.767 = 477.13(N) | 1 | Accept 478 (N) (A=1.77$mm^2$) or 486 (N) (A = 1.8 $mm^2$) |
| | | | | **[2]** | |
| | | **(ii)** | *F x d* | | Allow ecf from b (i) throughout |
| | | | 477.13 x 23 (= 10973.99) (Nmm) or (10.97399) (Nm) soi | 1 | Output force x distance |
| | | | $F_{IN}$ x (197-23) = 174 $F_{IN}$ | 1 | Input force x distance Allow d = 197 for this mark |
| | | | *F* = 63.1(N) | 1 | Using d = 197 gives $F_{IN}$ = 55.7 (N) for a total of 2 marks |
| | | | **Alternative method** | | Allow ecf from b (i) throughout |
| | | | $\frac{F_O}{F_{IN}} = \frac{a}{b}$ = MA | | |
| | | | $\frac{477.13}{F_{IN}} = \frac{174}{23}$ (= 7.565) | 1 | Substitution into formula, allow d = 197 for this mark |
| | | | $F_{IN} = \frac{477.13 \times 23}{174} = \frac{(477.13)}{7.565}$ | 1 | Transposition, allow d = 197 for this mark |
| | | | $F_{IN}$ = 63.1 (N) | 1 | Using d = 197 gives $F_{IN}$ = 55.7 (N) for a total of 2 marks |
| | | | | **[3]** | |

| Question | | | Answer/Indicative content | Mark | Guidance |
|---|---|---|---|---|---|
| 3 | (a) | | (25.2 x 1000) / 60 / 60 = 7 $ms^{-1}$ | 1 | Conversion of units |
| | | | KE = ½ $mv^2$ = ½ x 73 x $v^2$ | 1 | Use of formula for KE (v = 25.2 gives 23178.96) |
| | | | ½ x 73 x $7.0^2$ =1788.5 | 1 | |
| | | | J | 1 | Unit Unit 2 LO 2.4<br>Allow $kgm^2s^{-2}$, Nm oe do NOT allow j or n<br>Accept units with correct prefix for *their* answer eg 1.7885 kJ |
| | | | | **[4]** | |
| | **(b)** | | | | Allow ecf from (a) throughout, for v or KE |
| | | | mgh = 1788.5 | 1 | Use of conservation of energy |
| | | | ∴ 1788.5 / (73 x 9.8) = 2.5 (m) (vertical distance) | 1 | Use of conservation of energy<br>SC If conservation of energy is not used for finding vertical distance = 2.5 m, 1 mark only<br>If v = 25.2 is used in a suvat equation, vertical distance = 32.4 (m) for 1 mark only |
| | | | sin 7 = 2.5 / Overall distance travelled | 1 | Attempt to find Final distance, using *their* vertical distance |
| | | | ∴ Overall distance travelled = 20.514 (m) | 1 | Unit 1 LO 4.3<br>SC If conservation of energy is not used then final correct answer = 3 marks maximum<br>If v = 25.2 is used in a suvat equation, Overall distance travelled = 265.9 (m) for 3 marks |
| | | | | **[4]** | |

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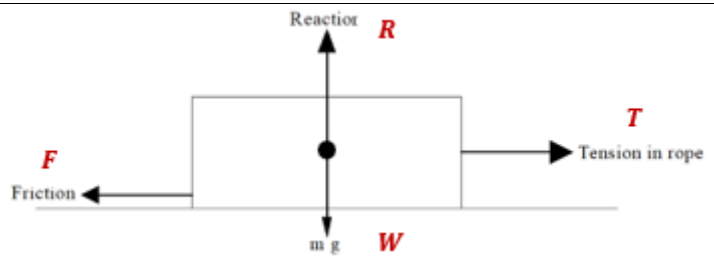
| Question | | | Answer/Indicative content | Mark | Guidance |
|---|---|---|---|---|---|
| 4 | (a) | | 14.5 x 9.8<br>= 142.1 (N) | 1<br>1 | Use of $R$ = mg<br>Allow awrt 142 |
| | | | | [2] | |
| | (b) | | $f_R = \mu R = 0.4 \times 14.5 \times 9.8$<br>= 56.84 (N) | 1<br>1 | Allow ecf from 4 (a) throughout<br>Use of $f_R = \mu R$ and substitution<br>Allow awrt 57 |
| | | | | [2] | |
| | (c) | |  | 1<br><br><br><br>1 | Accept *their* numerical values or clear initials<br>Vertical forces<br>for mg allow W or weight or 14.5g but NOT g by itself<br>for reaction allow normal<br>Horizontal allow pull(ing) or applied/driving force or drag or wtte<br>do **NOT** allow thrust/movement/acceleration<br>Ignore air resistance |
| | | | | [2] | |
| | (d) | | F = ma<br>$85-56.84 = 14.5\,a \quad \therefore \quad 28.16 = 14.5\,a$<br>$a$ = 1.94 ($ms^{-2}$) do **NOT** allow 2 ($ms^{-2}$) to 1sf | 1<br>1 | Allow ecf from (b)<br>Use of F = ma and substitution<br>Allow $a$ = 1.93 ($ms^{-2}$) if F = 57 is used<br>SC Allow 1 mark for a = 85/14.5 = 5.86 ($ms^{-2}$)<br>Unit 2 LO 2.3 |
| | | | | [2] | |

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| Question | | | Answer/Indicative content | Mark | Guidance |
|---|---|---|---|---|---|
| 5 | (a) | | 900 cos 10 = 886.33 soi | 1 | Resolve 900N (horizontally) |
| | | | 900 sin 10 = 156.28 soi | 1 | Resolve 900N (vertically) |
| | | | P sin α = 900 cos 10 or P sin α = 886.33 | 1 | Attempt to equate total horizontal forces |
| | | | (P cos α) – (900 sin 10) = 2700 or P cos α = 2856.28 | 1 | Attempt to resolve forces in the vertical direction |
| | | | $P = \sqrt{(886.32^2 + 2856.28^2)}$ ∴ P = 2990.6 (N) awrt 3000 | 1 | Allow 2543.72 for vertical force which gives P = 2693.7 (N) |
| | | | $\alpha = \tan^{-1}(886.33 / 2856.28)$ ∴ α = 17.24° awrt 17° | 1 | Allow 2543.72 for vertical force which gives α = 19.21° |
| | | | | | **Alternative method for last 2 marks**<br>tan α =P sin α/P cos α=900 cos10/2856.28 = 0.3103..<br>$\alpha = \tan^{-1} 0.3103 = 17.24^o$ or if using 2543.72 α = 19.21°<br>P = 886.32/sin (17.24) = 2990.6 or if using sin (19.21) P = 2693.7 (N) |
| | | | | **[6]** | |
| | (b) | | $\bar{x}$ = (4 x 60) / 3π soi | 1 | Evidence of 4r/(3π) for centroid |
| | | | (25.5, 60.0) | 1 | Allow 25 |
| | | | | 1 | 60 |
| | | | | **[3]** | |
| | (c) | | Fd = 45 Nm soi | 1 | Evidence of Moment = F×d using *their* d (100, 103.1, 25, 0.103 or 0.025 only) |
| | | | F = 45 ÷ 0.1 = 450(N) | 1 | |
| | | | up(wards) | 1 | Allow an upwards arrow |
| | | | | **[3]** | |

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| Question | | | Answer/Indicative content | Mark | Guidance |
|---|---|---|---|---|---|
| 6 | (a) | | 4 x 20 = (80 kN 2 m from $R_A$) soi | 1 | Converting UDL to point load (at 2 m from $R_A$) |
| | | | 0 = (80 x 2) + (50 x 4.5) + (75 x 6) – ($R_B$ x 7) | 1 | Evidence of moment about one end (3 correct terms) |
| | | | $R_B$ = 119.3(kN) | 1 | |
| | | | Total force = 205 (kN) | 1 | Evidence to find sum of *their* vertical forces (20kN gives 145kN) |
| | | | $R_A$ = 205 – 119.3 = 85.7(kN) | 1 | Allow *their* total force – *their* value for $R_B$ |
| | | | | | **Alternative method for final mark** |
| | | | | | Evidence of moment about the other end (3 correct terms) |
| | | | | | 0 = (75 x 1) + (50 x 2.5) + (80 x 5) – ($R_A$ x 7) |
| | | | | | $R_A$ = 85.7 (kN) |
| | | | | | SC If $R_A$ and $R_B$ are the wrong way round, award 4 marks |
| | | | **Alternative method** | | |
| | | | 4 x 20 = 80 kN 2 m from $R_A$ | 1 | Converting UDL to point load at 2 m from $R_A$ |
| | | | 0 = (75 x 1) + (50 x 2.5) + (80 x 5) – ($R_A$ x 7) | 1 | Evidence of moment about one end (3 correct terms) |
| | | | $R_A$ = 85.7 (kN) | 1 | |
| | | | Total force = 205 (kN) | 1 | Evidence to find sum of *their* vertical forces (20kN gives 145kN) |
| | | | $R_B$ = 205 – 85.7 = 119.3 (kN) | 1 | Allow *their* total force – *their* value for $R_B$ |
| | | | | | **Alternative method for final mark** |
| | | | | | Evidence of moment about the other end (3 correct terms) |
| | | | | | 0 = (80 x 2) + (50 x 4.5) + (75 x 6) – ($R_B$ x 7) |
| | | | | | $R_B$ = 119.3 (kN) |
| | | | | | SC If $R_A$ and $R_B$ are the wrong way round, award 4 marks |
| | | | | **[5]** | |

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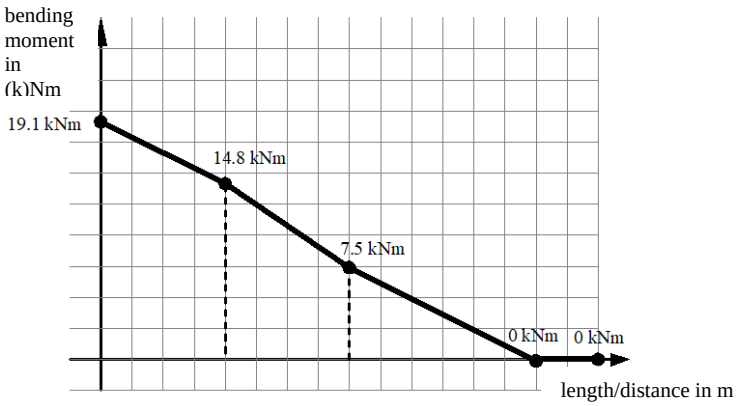
| Question | | | Answer/Indicative content | Mark | Guidance |
|---|---|---|---|---|---|
| 6 | (b) | | Vertical force at 2 m = 3 x sin50 (= 2.298 (kN)) | 1 | Vertical component of 3 kN force. Unit 2 LO2.1 |
| | | | BM @ 4 m = **0** (kNm) soi on graph | 1 | Bending moment at 4m **AND** 3.5m |
| | | | BM @ 3.5 m = **0** (kNm) soi on graph | | |
| | | | BM@ 2 m = 5 x 1.5 = **7.5** (kNm) soi on graph | 1 | Bending moment at 2 m |
| | | | BM @ 1 m = (1 x 2.298) + (2.5 x 5) = **14.8** (kNm) soi on graph | 1 | Bending moment at 1 m |
| | | | BM @ 0 m = (1 x -3) + (2 x 2.298) + (3.5 x 5) = **19.1** (kNm) soi on graph | 1 | Bending moment at 0 m |
| | | |  | 1<br>1 | Mapping 3 or more of *their* bending moments onto diagram<br>Axes labelled with (bending) moment and length/distance and/or units as shown<br><br>Do **NOT** penalise correct answers if working from right to left. |
| | | | | **[7]** | |

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