OCR
Oxford Cambridge and RSA

# GCE

## Further Mathematics B (MEI)

**Y431/01:** Mechanics minor

Advanced GCE

# Mark Scheme for November 2020

OCR (Oxford Cambridge and RSA) is a leading UK awarding body, providing a wide range of qualifications to meet the needs of candidates of all ages and abilities. OCR qualifications include AS/A Levels, Diplomas, GCSEs, Cambridge Nationals, Cambridge Technicals, Functional Skills, Key Skills, Entry Level qualifications, NVQs and vocational qualifications in areas such as IT, business, languages, teaching/training, administration and secretarial skills.

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.

© OCR 2020

## 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(a) | $12 = \frac{1}{3}h$ | M1 | 1.1 | Uses the fact that the height of the centre of mass is the same for both solids | This mark may be implied by sight of correct answer |
| | $h = 36$ | A1 [2] | 1.1 | | |
| 1(b) | $\tan\alpha = \frac{6}{12}$ | M1 | 1.1 | For using $\tan\alpha = \frac{\frac{1}{2}w}{12}$ (allow reciprocal) | or $\alpha + \tan^{-1}\frac{12}{6} = 90$ |
| | $\alpha = 26.6$ | A1 [2] | 1.1 | | For reference: 26.5650511… |
| 1(c) | $288\times12 + \left(24 + \frac{1}{3}h\right)(6h) = (288 + 6h)\bar{y}$ | M1 | 2.1 | Takes moments about base of compound shape – correct number of terms and dimensionally consistent | Allow with their $h$ from (a) |
| | $\bar{y} = \frac{156}{7}$ | A1 [2] | 2.2a | oe | 22.28571429… |
| 2(a) | $[\text{pressure}] = \text{MLT}^{-2}\text{L}^{-2}\left(= \text{ML}^{-1}\text{T}^{-2}\right)$ | B1 | 1.1 | Allow unsimplified | Both these two B marks may be implied by later working |
| | $[\text{density}] = \text{ML}^{-3}$ | B1 | 1.2 | | |
| | $\text{LT}^{-1} = \text{M}^{\alpha}\text{L}^{-\alpha}\text{T}^{-2\alpha}\text{M}^{\beta}\text{L}^{-3\beta} = \text{M}^{\alpha+\beta}\text{L}^{-\alpha-3\beta}\text{T}^{-2\alpha}$ | M1* | 1.1 | Substituting into $c = kp^{\alpha}d^{\beta}$ with correct LHS and their expressions for pressure and density (with $[k]=1$) | |
| | $\alpha+\beta=0, -\alpha-3\beta=1, -2\alpha=-1$ | M1dep* | 1.1 | Setting up at least two equations and attempting to solve for both $\alpha$ and $\beta$ | |
| | $\alpha = \frac{1}{2}$, $\beta = -\frac{1}{2}$ | A1 | 1.1 | Both correct | |

| | | | | | |
|---|---|---|---|---|---|
| | | **[5]** | | | |
| **2(b)** | $(1.01)^{\alpha}(0.995)^{\beta}(340)$<br>342.55 ($m\,s^{-1}$) | **M1**<br>**A1ft**<br>**[2]** | **3.1b**<br>**2.2b** | Correct method for finding new speed allow 1 incorrect multiplier.<br>ft their $\alpha$ *and* $\beta$ only | With their values of $\alpha$ *and* $\beta$ from (a)<br>342.55322735… |
| **3(a)** | $\mathbf{R} = (c-1)\mathbf{i} + \left(2\sqrt{c}\right)\mathbf{j}, R = \sqrt{(c-1)^2 + 4c}$<br>$= \sqrt{c^2+2c+1} = \sqrt{(c+1)^2} = c+1$ * | **M1**<br>**A1**<br>**[2]** | **1.1**<br>**2.2a** | Modulus (or modulus squared) of $R$ stated correctly<br>**AG** | |
| **3(b)** | $8(c+1) = 900(6-v)$<br>$6 - \frac{8}{900}(c+1) > 0$<br>$(0<)c < 674$ | **M1***<br>**M1dep***<br>**A1**<br>**[3]** | **3.3**<br>**3.4**<br>**1.1** | Applies impulse = change in momentum (allow sign errors) or application of N2L.<br>Uses the fact that $v > 0$ or considers the limiting case when $v = 0$<br>Must be strict inequality | Where $v$ is the speed of the car at B |
| **3(c)** | $18000 = 5D$<br>$\frac{18000}{5} - (c+1) = 900 \times 3.5$<br>$c = 449$ | **B1**<br>**M1**<br>**A1**<br>**[3]** | **1.1**<br>**3.3**<br>**1.1** | Applies N2L – correct number of terms (allow $D$ for tractive force) – condone sign errors | Where $D$ is the tractive force |
| **3(d)** | Model resistance as varying or model the power as not constant. | **B1**<br>**[1]** | **3.5c** | Any alternative correct reason e.g. air resistance incorporated into the model. | |
| **4** | $R = 20g\cos 30$ | **M1*** | **3.3** | Resolving normal to the plane – correct number of terms (allow cos/sin confusion and sign errors) | $R$ is the normal contact force between the block and the plane |

| | | | | | |
|---|---|---|---|---|---|
| | $F = \frac{\sqrt{3}}{49}(20g\cos 30)$ | **M1dep*** | **3.4** | Use of $F = \mu R$ with their $R$ | For reference $F = 6$ (where F is the frictional contact between the block and the plane) |
| | Loss in KE = $\frac{1}{2} \times 20\left(9^2 - 4^2\right)(= 650)$ | **B1** | **1.1** | Calculates the difference in KE | Allow $\pm\frac{1}{2} \times 20\left(9^2 - 4^2\right)$ |
| | Gain in PE = $20gx\sin 30$ | **M1** | **1.1** | Attempts gain in PE – allow cos/sin confusion | M0 for $20gx$ |
| | $= 10gx$ | **A1** | **1.1** | For $20\ gx\ sin\ 30$ oe | |
| | $20gx\sin 30 - \frac{1}{2} \times 20\left(9^2 - 4^2\right) = Tx - \frac{\sqrt{3}}{49}x(20g\cos 30)$ | **M1*** | **3.3** | Work energy principle – including their change in KE, change in PE and work done against friction and dimensionally consistent – allow sign errors | Where $T$ is the magnitude of the pulling force (condone if implied that this term is zero) |
| | $20gx\sin 30 - \frac{1}{2} \times 20\left(9^2 - 4^2\right) + \frac{\sqrt{3}}{49}x(20g\cos 30) > 0$ | **M1dep*** | **3.1b** | Considers the case when $T > 0$ – leading to a value(s) for $x$ or when $T = 0$ | |
| | $x > \frac{650}{10g + 6}$<br>$x > 6.25$ | **A1**<br><br>**[8]** | **2.5** | Must be strict inequality for this mark | |
| **5(a)** | Weight of small object acting vertically downwards at B.<br>Weight of the rod acting vertically downwards at the midpoint of AB.<br>Normal contact force acting vertically upwards at A.<br>Frictional contact force acting horizontally to the right at A. | **B2**<br><br>**[2]** | **1.2**<br>**1.2** | B1 for any three correct | |
| **5(b)** | $3mga\cos 60 + mg(2a\cos 60) = \frac{6}{5}aT\cos(60 - \theta)$ | **M1** | **3.3** | Moments about A – of their forces at least 2 terms | |

| | | | | | |
|---|---|---|---|---|---|
| | $\frac{3}{2}mga + mga = T\left(\frac{3}{5}a\cos\theta + \frac{6\sqrt{3}}{10}\ a\sin\theta\right)$ | **A1** | **1.1** | Left-hand side correct<br>oe for right-hand side e.g.<br>$T\left(\frac{6}{5}a\cos 60\cos\theta + \frac{6}{5}\sin 60\ a\sin\theta\right)$<br>or $\frac{6}{5}aT\sin(30+\theta)$ | |
| | $\therefore 25mg = T(6\cos\theta + 6\sqrt{3}\sin\theta)$<br>$T = \frac{25mg}{6(\cos\theta + \sqrt{3}\sin\theta)}$ | **A1**<br>**[4]** | **2.2a** | **AG** | |
| **5(c)** | $F = T\sin\theta$ | **B1** | **1.1** | Resolving horizontally | $F$ is the frictional contact force at A where T is the force applied at C |
| | | **M1*** | **3.3** | Resolving vertically – correct number of terms from their force diagram | |
| | $R + T\cos\theta = 3mg + mg$ | **A1** | **1.1** | | $R$ is the normal contact force at A |
| | $F = \mu R$<br>$T\sin\theta = \mu(4mg - T\cos\theta)$ | **M1*** | **3.4** | Applying $F = \mu R$ with correct $T$ and their $F$ and $R$ | |
| | $\frac{25mg\sin\theta}{6\left(\cos\theta+\sqrt{3}\sin\theta\right)} = \frac{3}{4}\left(4mg - \frac{25mg\cos\theta}{6\left(\cos\theta+\sqrt{3}\sin\theta\right)}\right)$ | **A1** | **1.1** | Correct equation in cosine and sine | |
| | $25\sin\theta = \frac{3}{4}\left(24\sqrt{3}\sin\theta - \cos\theta\right) \Rightarrow \tan\theta = \frac{\frac{3}{4}}{18\sqrt{3}-25}$ | **M1dep*** | **3.1a** | Re-arranges and uses tan = sin / cos | Dependent on all M marks and the B mark |

| | | | | | |
|---|---|---|---|---|---|
| | $\theta = 6.92$ | **A1** **[7]** | **1.1** | | 6.922956141… |
| **6(a)** | $mu = -mv_A + 3mv_B$ | **M1*** | **3.3** | Conservation of linear momentum – correct number of terms but allow sign errors | Correct initial speed $u$ must be used |
| | $-v_A - v_B = -eu$ | **M1*** | **3.3** | Newton's experimental law – correct number of terms – must be consistent with CLM | |
| | | **M1dep*** | **3.4** | Solves both equations to find $v_A$ | |
| | $v_A = \frac{1}{4}(3e-1)u$ | **A1** | **1.1** | Correct expression for speed of A after collision | |
| | $v_A > 0 \Rightarrow e > \frac{1}{3}$ | **A1** **[5]** | **2.2a** | | |
| **6(b)** | $v_B = \frac{1}{4}(1+e)u$ | **B1** | **1.1** | Correct expression for speed of B after collision | May be seen in (a) but must be used in this part |
| | $w_B = \frac{1}{4}e(1+e)u$ | **B1ft** | **3.4** | Speed of B after collision with the wall (follow through their $v_B$) | |
| | $w_B - v_A = \frac{1}{4}e(1+e)u - \frac{1}{4}(3e-1)u = \frac{1}{4}(e-1)^2 u$ | **M1** | **3.1b** | Correctly compares speed of A and B after both collisions | |
| | $w_B > v_A$ unless $e = 1$ | **A1** **[4]** | **2.2a** | **AG** checking case when e =1 is insufficient | |
| **6(c)** | Kinetic energy is likely to be lost during the collisions (for example, likely to be converted into heat or sound) | **B1** **[1]** | **3.5b** | Must mention kinetic energy lost or energy converted to other forms. | |
| **6(d)** | Initial KE = $\frac{1}{2}mu^2$ | **B1** | **1.1** | | |
| | KE after collision = $\frac{1}{2}mu^2\left(\frac{1}{16}(3e-1)^2\right) + \frac{1}{2}(3m)u^2\left(\frac{1}{16}(1+e)^2\right)$ | **B1ft** | **1.1** | Correct expression following through their $v_A$ and $v_B$ | |

| | | | | | |
|---|---|---|---|---|---|
| | $\frac{1}{2}mu^2 - \frac{1}{2}mu^2\left(\frac{1}{16}(3e-1)^2\right) - \frac{1}{2}(3m)u^2\left(\frac{1}{16}(1+e)^2\right) = \frac{5}{24}mu^2$<br>$e = \frac{2}{3}$ | **M1**<br>**A1**<br>**[4]** | **1.1**<br>**1.1** | Set up an equation involving change in KE and $\frac{5}{24}mu^2$ and solves for $e$ | |
| **6(e)** | $\frac{x-2}{v_A} = \frac{2}{v_B} + \frac{x}{w_B}$<br>$\frac{x-2}{\frac{1}{4}u} = \frac{2}{\frac{5}{12}u} + \frac{x}{\frac{5}{18}u} \Rightarrow 4(x-2) = \frac{24}{5} + \frac{18x}{5}$<br>$x = 32\,(\text{m})$ | **M1***<br>**M1dep***<br>**A1**<br>**[3]** | **3.1b**<br>**3.4**<br>**2.2a** | Equate times in terms of required distance $x$<br>Substitutes their speeds (with their value of $e$) and solve for their $x$ | |

**OCR (Oxford Cambridge and RSA Examinations)**
**The Triangle Building**
**Shaftesbury Road**
**Cambridge**
**CB2 8EA**

**OCR Customer Contact Centre**

**Education and Learning**
Telephone: 01223 553998
Facsimile: 01223 552627
Email: general.qualifications@ocr.org.uk

**www.ocr.org.uk**

For staff training purposes and as part of our quality assurance programme your call may be recorded or monitored

Cambridge Assessment