# Mark Scheme (Results)

## October 2022

Pearson Edexcel International Advanced Level

in Mechanics M2 (WME02)

Paper 01

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## General Marking Guidance

- All candidates must receive the same treatment. Examiners must mark the first candidate in exactly the same way as they mark the last.
- Mark schemes should be applied positively. Candidates must be rewarded for what they have shown they can do rather than penalised for omissions.
- Examiners should mark according to the mark scheme not according to their perception of where the grade boundaries may lie.
- There is no ceiling on achievement. All marks on the mark scheme should be used appropriately.
- All the marks on the mark scheme are designed to be awarded. Examiners should always award full marks if deserved, i.e. if the answer matches the mark scheme. Examiners should also be prepared to award zero marks if the candidate's response is not worthy of credit according to the mark scheme.
- Where some judgement is required, mark schemes will provide the principles by which marks will be awarded and exemplification may be limited.
- When examiners are in doubt regarding the application of the mark scheme to a candidate's response, the team leader must be consulted.
- Crossed out work should be marked UNLESS the candidate has replaced it with an alternative response.

# EDEXCEL IAL MATHEMATICS

## General Instructions for Marking

1. The total number of marks for the paper is 75.

2. The Edexcel Mathematics mark schemes use the following types of marks:

- M marks: Method marks are awarded for 'knowing a method and attempting to apply it', unless otherwise indicated.
- A marks: Accuracy marks can only be awarded if the relevant method (M) marks have been earned.
- B marks are unconditional accuracy marks (independent of M marks)
- Marks should not be subdivided.

3. Abbreviations

These are some of the traditional marking abbreviations that will appear in the mark schemes and can be used if you are using the annotation facility on ePEN.

- bod – benefit of doubt
- ft – follow through
- the symbol $\surd$ will be used for correct ft
- cao – correct answer only
- cso - correct solution only. There must be no errors in this part of the question to obtain this mark
- isw – ignore subsequent working
- awrt – answers which round to
- SC: special case
- oe – or equivalent (and appropriate)
- d… or dep – dependent
- indep – independent
- dp decimal places
- sf significant figures
- * The answer is printed on the paper or ag- answer given
- $\sqsubset$ or d… The second mark is dependent on gaining the first mark

4. All A marks are 'correct answer only' (cao.), unless shown, for example, as A1 ft to indicate that previous wrong working is to be followed through. After a misread however, the subsequent A marks affected are treated as A ft, but manifestly absurd answers should never be awarded A marks.

5. For misreading which does not alter the character of a question or materially simplify it, deduct two from any A or B marks gained, in that part of the question affected. If you are using the annotation facility on ePEN, indicate this action by 'MR' in the body of the script.

6. If a candidate makes more than one attempt at any question:
   - If all but one attempt is crossed out, mark the attempt which is NOT crossed out.
   - If either all attempts are crossed out or none are crossed out, mark all the attempts and score the highest single attempt.

7. Ignore wrong working or incorrect statements following a correct answer.

## General Principles for Mechanics Marking

*(But note that specific mark schemes may sometimes override these general principles)*

- Rules for M marks: correct no. of terms; dimensionally correct; all terms that need resolving (i.e. multiplied by cos or sin) are resolved.
- Omission or extra g in a resolution is an accuracy error not method error.
- Omission of mass from a resolution is a method error.
- Omission of a length from a moments equation is a method error.
- Omission of units or incorrect units is not (usually) counted as an accuracy error.
- DM indicates a dependent method mark i.e. one that can only be awarded if a previous specified method mark has been awarded.
- Any numerical answer which comes from use of g = 9.8 should be given to 2 or 3 SF.
- Use of g = 9.81 should be penalised once per (complete) question.

N.B. Over-accuracy or under-accuracy of correct answers should only be penalised *once* per complete question. However, premature approximation should be penalised every time it occurs.

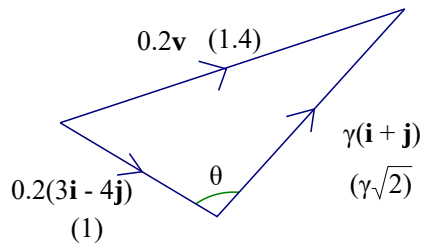
- Marks must be entered in the same order as they appear on the mark scheme.
- In all cases, if the candidate clearly labels their working under a particular part of a question i.e. (a) or (b) or (c),……then that working can only score marks for that part of the question.
- Accept column vectors in all cases.
- Misreads – if a misread does not alter the character of a question or materially simplify it, deduct two from any A or B marks gained, bearing in mind that after a misread, the subsequent A marks affected are treated as A ft

Mechanics Abbreviations

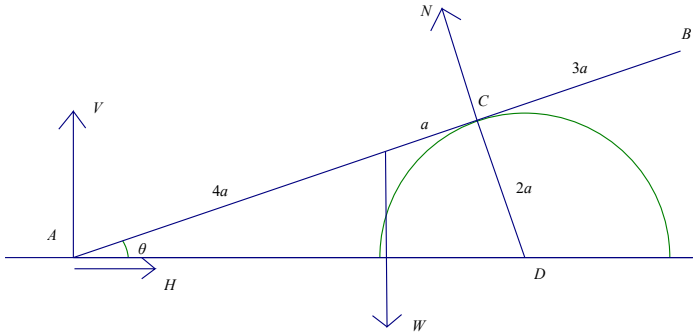
| | |
|---|---|
| M(A) | Taking moments about A. |
| N2L | Newton's Second Law (Equation of Motion) |
| NEL | Newton's Experimental Law (Newton's Law of Impact) |
| HL | Hooke's Law |
| SHM | Simple harmonic motion |
| PCLM | Principle of conservation of linear momentum |
| RHS, LHS | Right hand side, left hand side. |

| Q | Mark Scheme | Marks | Marking guidance |
|---|---|---|---|
| **1** (a) | M($x$ axis) | M1 | Need all terms. Dimensionally consistent. Condone if $m$ missing throughout. Accept as part of a vector equation |
| | $2m\times(-2)+3m\times 2+4m\times 3k=9m\times\bar{x}$ $\bar{x}=\dfrac{2+12k}{9}$ * | A1* | Obtain given result |
| | | **2** | |
| (b) | M($y$ axis) | M1 | Need all terms. Dimensionally consistent. Might be seen as part of a vector equation in (a). It does not score any marks until referred to in part (b). Condone if $m$ missing throughout. |
| | $2m\times 5+3m\times(-3)+4m\times k=9m\times\bar{y}$ $\left(\bar{y}=\dfrac{1+4k}{9}\right)$ | A1 | Correct unsimplified equation. Allow if $m$ missing throughout. |
| | Form and solve equation in $k$ $(2+12k+2+8k=27)$ | DM1 | Use their $\bar{y}$ and $\bar{x}+2\bar{y}=3$ Dependent on the two preceding M marks |
| | $k=\dfrac{23}{20}\quad(1.15)$ | A1 | Correct answer only |
| | | **4** | |
| | | **(6)** | |

| Q | Mark Scheme | Marks | Marking guidance |
|---|---|---|---|
| **2** | Use of $P = Fv$ | M1 | Seen or implied e.g. $F = \frac{15000}{16}\left(=937.5\right)$<br>Condone 15 in place of 15000 or extra zeros on 15000 |
| | Equation of motion | M1 | Need all terms. Condone sign errors and sin / cos confusion. Dimensionally consistent. |
| | $F + 900g\sin\theta - 400 = 900a$ | A1 | Unsimplified equation in *P* or their *F* with at most one error |
| | $\frac{15000}{16} + 900g \times \frac{1}{12} - 400 = 900a$ | A1 | Correct unsimplified equation with *F* and $\sin\theta$ substituted |
| | $a = 1.41 \quad (1.4) \quad \left(\text{m s}^{-2}\right)$ | A1 | 3sf or 2sf |
| | | **(5)** | |

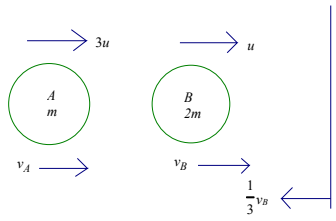
| Q | Mark Scheme | Marks | Marking guidance |
|---|---|---|---|
| **3.** | Use of $\mathbf{I} = m\mathbf{v} - m\mathbf{u}$ | M1 | Accept equivalent e.g. $\mathbf{I}+m\mathbf{u}= m\mathbf{v}$ . Dimensionally correct and must be using subtraction (but could be the wrong way round). The use of 7 in place of the velocity in the impulse momentum equation is M0 unless they recover. **See below** |
| | $0.2(\mathbf{v}-4\mathbf{i}+3\mathbf{j}) = \lambda(\mathbf{i}+\mathbf{j})$<br>$((x-4)\mathbf{i}+(y+3)\mathbf{j} = 5\lambda\mathbf{i}+5\lambda\mathbf{j})$ | A1 | Correct unsimplified vector equation or pair of separate equations for the **i** and **j** components.<br>Condone column vectors with **i** and **j** included in the components. |
| | Use of Pythagoras for the speed | M1 | Correct use of Pythagoras and 49 for their speed |
| | $x^2 + y^2 = 49$ | A1 | Correct unsimplified equation for their $x$, $y$ |
| | Form quadratic in $x, y$ or $\lambda$ and solve for $\lambda$ | DM1 | Dependent on both previous M marks. $x^2 +$ $-(x\ 7)^2 = 49$ or $(y+7)^2 + = y^2\ 49$ or $(5\lambda + 4)^2$ $+(5\lambda - =3)^2\ 49$ |
| | $\lambda = \frac{3}{5}$ or $\lambda = -\frac{4}{5}$ | A1 | Or equivalent |
| ** ** ** ** ** ** ** ** | Special case: Candidates who use 7 as a vector can score a **maximum** of M1A0M1A0 for<br>$1.4^2 = +(\lambda\ 0.8)^2 + -(\lambda\ 0.6)^2$ or equivalent<br><br>DM1A0 for forming and solving a quadratic in λ. | | This maximum of 3 marks is only available for those candidates who "recover".<br>So, **if all you see** is $\lambda\ \lambda\mathbf{i}+ = -\mathbf{j}$<br>$1.4 \quad 0.2 \quad 4(\mathbf{i}-3\mathbf{j})$<br>they score M0M0M0<br>If they recover to go on to form a "sensible" equation using Pythagoras then they can score the first 2 M marks, and potentially the third M1 as well. |
| | | **(6)** | |
| **3** alt |  | | |
| | Form vector triangle | M1 | Dimensionally correct. Allow incorrect configuration |
| | Correct triangle and correct lengths | A1 | In speeds or momentum but not a mixture |
| | Use scalar product to find cosine of angle | M1 | Or equivalent method |
| | $\cos\theta = -\frac{1}{5\sqrt{2}}$ | A1 | Allow ± |
| | Form equation in $\lambda$<br>$(2\lambda^2 + .4\lambda - 0.96 = 0)$ | DM1 | e.g. by use of cosine rule<br>Dependent on the first 2 M marks |
| | $\lambda = \frac{3}{5}$ or $\lambda = -\frac{4}{5}$ | A1 | Or equivalent |
| | | **(6)** | |

| Q | Mark Scheme | Marks | Marking guidance |
|---|---|---|---|
| **4** (a) | $\lambda^2+2\lambda-3=0\left(=(\lambda+3)(\lambda-1)\right)$ | M1 | Set **j** component = 0 and solve for $\lambda$ |
| | $\Rightarrow \lambda=1$ | A1 | Only. Seen or implied. Accept $t=1$ |
| | Use $\mathbf{a}=\dfrac{\mathrm{d}\mathbf{v}}{\mathrm{d}t}$ | M1 | Attempt derivative of both components with respect to $t$. Powers going down. Condone errors in dealing with the signs / indices for the square root. The answer must be a vector. |
| | $=\dfrac{-1}{2\sqrt{5-t}}\mathbf{i}+(2t+2)\mathbf{j}$ | A1 | Any equivalent form |
| | $=-\dfrac{1}{4}\mathbf{i}+4\mathbf{j}$ | A1 | Only. Any equivalent form. ISW if they go on to find the magnitude. |
| | | **5** | |
| **4** (b) | Use $\mathbf{s}=\int \mathbf{v}\,\mathrm{d}t$ | M1 | Attempt integral of both components. (M0 if they have assumed that one component is zero) Powers going up. Condone errors in dealing with the signs / indices for the square root. |
| | $\mathbf{s}=\left(-\dfrac{2}{3}(5-t)^{\frac{3}{2}}(+A)\right)\mathbf{i}+\left(\dfrac{1}{3}t^3+t^2-3t(+B)\right)\mathbf{j}$ | A1<br><br>A1 | Unsimplified expression with error in at most one term Correct unsimplified expression. Allow with no constant(s) of integration |
| | Use $t=1, \mathbf{s}=-2\mathbf{i}+\mathbf{j}$ | DM1 | Use of initial condition to find constant(s) of integration. Dependent on the previous M1. |
| | $\mathbf{s}=\left(-\dfrac{2}{3}(5-T)^{\frac{3}{2}}+\dfrac{10}{3}\right)\mathbf{i}+\left(\dfrac{1}{3}T^3+T^2-3T+\dfrac{8}{3}\right)\mathbf{j}$ | A1 | Any equivalent form for the position vector |
| | | **5** | |
| | | **(10)** | |

| Q | Mark Scheme | Marks | Marking guidance |
|---|---|---|---|
| |  | | |
| **5** (a) | $AD = \sqrt{(2a)^2 + (5a)^2} = \sqrt{29}a$ * | B1* | Correct use of Pythagoras to show **given answer** from correct working (need $a$ on both sides) |
| | | **1** | |
| **5** (b) | M($A$): $W \times 4a\cos\theta = N \times 5a$ | M1 | Dimensionally correct equation in $a$. Allow if $a$ cancelled. Condone sin/cos confusion |
| | $W \times 4a \times \frac{5}{\sqrt{29}} = N \times 5a$ | A1 | Correct unsimplified equation. Allow with $\cos\theta$.<br>NB: $5a = \sqrt{29}a\cos\theta$ |
| | $N = \frac{4}{\sqrt{29}}W$ * | A1* | Obtain **given answer** from correct working |
| | | **3** | |
| **5** (c) | The candidates need to form sufficient equations to solve for $k$ and $\tan\alpha$. There should be two independent equations. Allow M1A1 for the first equation seen, and M1A1 for the second equation. If there are more than 2 equations, award the marks for the equations used to solve for $k$ and $\tan\alpha$. If they stop after forming the equations, allow the marks for the best 2 equations. | | |
| | Resolve vertically | M1 | Requires all relevant terms. Condone sin / cos confusion |
| | $V + N\cos\theta = W \quad \left(V = \frac{9}{29}W\right)$<br>or $kW\sin\alpha + N\cos\theta = W$ | A1 | Correct unsimplified equation. Need not substitute for trig. |
| | Resolve horizontally | M1 | Requires all relevant terms. Condone consistent sin / cos confusion |
| | $H = N\sin\theta\left(=\frac{8}{29}W\right)$ or $kW\cos\alpha = N\sin\theta\left(=\frac{8}{29}W\right)$ | A1 | Correct unsimplified equation. Need not substitute for trig. |
| | Possible alternative equation for M1A1 using M($C$):<br>$aW\cos\theta + 5aH\sin\theta = 5aV\cos\theta$<br>or $aW\cos\theta = kW \times 5a\sin(\alpha - \theta)$ | | |
| | Use Pythagoras to obtain $k$: $k^2 = \left(\frac{9}{29}\right)^2 + \left(\frac{8}{29}\right)^2$ | DM1 | Correct use of perpendicular components.<br>Dependent on the first 2 M marks |

| | | | |
|---|---|---|---|
| | $k = \frac{\sqrt{145}}{29} = \sqrt{\frac{5}{29}}$ | A1 | Correct only. Any equivalent exact form<br>(ISW but 0.415 with no exact answer seen is A0) |
| | Use trig to obtain $\tan\alpha$ | DM1 | Dependent on the first 2 M marks |
| | $\tan\alpha = \frac{9}{8}$ | A1 | Correct only. Must be a simplified number. Do not accept answer including $W$ |
| | | **8** | |
| **5** (c) alt | Resolve parallel to rod | M1 | Requires all relevant terms. Condone sin / cos confusion |
| | $F = W\sin\theta \left( = \frac{2}{\sqrt{29}}W \right)$ | A1 | Correct unsimplified equation. Need not substitute for trig. |
| | Resolve perpendicular to rod | M1 | Requires all relevant terms. Condone consistent sin / cos confusion |
| | $E + N = W\cos\theta \quad \left( E = \frac{1}{\sqrt{29}}W \right)$ | A1 | Correct unsimplified equation. Need not substitute for trig. |
| | Possible alternative equation for M1A1 using M($C$) :<br>$aW\cos\theta + 5aH\sin\theta = 5aV\cos\theta$<br>or $aW\cos\theta = kW \times 5a\sin(\alpha - \theta)$ | | |
| | Use Pythagoras to obtain $k$ | M1 | Correct use of Pythagoras |
| | $k = \frac{1}{\sqrt{29}}\sqrt{1+4} = \sqrt{\frac{5}{29}}$ | A1 | Correct only |
| | Use trig to obtain $\tan\alpha$ : $\tan(\alpha - \theta) = \frac{1}{2} = \frac{\tan\alpha - \frac{2}{5}}{1 + \frac{2}{5}\tan\alpha}$ | DM1 | Use of trig to obtain expression in $\tan\alpha$ |
| | $\tan\alpha = \frac{9}{8}$ | A1 | Correct only |
| | | **8** | |
| | | **(12)** | |

| Q | Mark Scheme | Marks | Marking guidance |
|---|---|---|---|
| **6** (a) | M($PV$) | M1 | Allow use of a parallel axis. Terms dimensionally consistent. Could be seen as part of a vector equation. Condone error(s) in distance(s). |
| | $a\times 2ka^2+\left(2a+\frac{1}{2}ka\right)2ka^2=\bar{x}\times\left(2ka^2+2ka^2\right)$ | A1 | Correct unsimplified equation |
| | $2\bar{x}=a+2a+\frac{1}{2}ka \Rightarrow \bar{x}=\frac{6+k}{4}a$ * | A1* | Obtain **given answer** from correct working |
| | | **3** | |
| **6** (b) | M($PR$) | M1 | Allow use of a parallel axis. Terms dimensionally consistent. Could be seen as part of a vector equation in (a) but needs to be used here to score mark(s) in (b). Condone error(s) in distance(s).<br>If working from $VU$ they might assume that c of m of $QRST$ lies on their axis. So long as they say that this is what they have done (e.g. in a table of values) this can score M1A0A0M1A1ftA0. |
| | $\frac{1}{2}ka\times 2ka^2+a\times 2ka^2=\bar{y}\times 4ka^2$ | A1 | Correct unsimplified equation |
| | $\bar{y}=\frac{k+2}{4}a$ | A1 | Correct answer $(\pm)$ seen or implied<br>Accept distance from<br>$VU=\pm\frac{3k-2}{4}a$<br>Or distance from TS = $\pm\frac{6-k}{4}a$ |
| | Use angle to form equation in $k$ | M1 | Correct use of given ratio. Allow reciprocal |
| | $\frac{7}{15}=\frac{\bar{y}}{\bar{x}}=\frac{(k+2)a}{4}\times\frac{4}{(6+k)a}$ | A1 | Correct unsimplified equation using given $\bar{x}$ and their $\bar{y}$<br>e.g. $\frac{ka-\bar{y}_{VU}}{\bar{x}}$ or $\frac{2a-\bar{y}_{TS}}{\bar{x}}$ |
| | $\Rightarrow k=\frac{3}{2}(=1.5)$ | A1 | Correct only |
| | | **6** | |
| | | **(9)** | |

| Q | Mark Scheme | Marks | Marking guidance |
|---|---|---|---|
| **7** (a) |   | | Check their diagram but remember that the directions used in their equations might not be consistent with the diagram. In this case, ignore their diagram. |
| | Conservation of momentum | M1 | Need all terms. Dimensionally correct. Condone sign errors. Condone *m* missing throughout or *g* present throughout. |
| | $3mu + 2mu = mv_A + 2mv_B \quad (5u = v_A + 2v_B)$ | A1 | Correct unsimplified equation. Allow with $v_A$ negative |
| | Use of NEL | M1 | Used the right way round. Condone sign errors |
| | $v_B - v_A = e(3u - u) \qquad (2ue = v_B - v_A)$ | A1 | Correct unsimplified equation. Allow with $v_A$ negative. Signs consistent between the two equations. |
| | Solve for $v_A$ or $v_B$ | DM1 | Dependent on two previous M marks |
| | Obtain $v_B = \frac{5+2e}{3}u$ * | A1* | Obtain **given answer** from correct working |
| | Obtain $v_A = \frac{5-4e}{3}u$ | A1 | Or equivalent. $v_A$ must be positive |
| | | **7** | |
| **7** (b) | Time for *B* to reach the wall $t_B = \frac{d}{2u}$ | B1 | Seen or implied. Allow $\frac{d \times 3}{(5+2e)u}$ |
| | Speed of *B* after impact with wall $= \frac{2}{3}u$ | B1 | Seen or implied. Allow $\frac{1}{3}\left(\frac{5+2e}{3}\right)$ |
| | Distance travelled by *A* before *B* hits the wall $= u \times \frac{d}{2u}\left(= \frac{d}{2}\right)$ | M1 | Substitute $e = \frac{1}{2}$ and use their $v_A$ and their $t_b$ to find distance |
| | Time to close the gap | M1 | Correct formula with their relevant speeds |
| | $\frac{d}{2} = u \times t + \frac{2u}{3} \times t\left(= \frac{5ut}{3}\right) \quad \left(t = \frac{3d}{10u}\right)$ | A1 | Correct unsimplified equation |
| | Total time $= \frac{d}{2u} + \frac{3d}{10u} = \frac{8d}{10u}\left(= \frac{4d}{5u}\right)$ | A1 | ISW Any equivalent form |
| | | **6** | |
| 7(b) alt | In time *T*, *A* travels *x* metres $x = uT$<br>*B* travels *d* metres in *t* sec<br>$d = 2ut$ First B1<br>*B* travels $d - x$ metres in *t*' sec<br>$d - x = 2ut'/3$ Second B1 and first M1<br>t + t' = T<br>(d + 3d – 3uT)/2u = T Second M1 and first A1<br>T = 4d/5u Second A1 | | Equivalent statement<br><br>Correct value implied and Distance travelled by *B* after it hits the wall<br>Correct formula for time and Correct unsimplified equation<br>Correct answer |
| | | **(13)** | |

| Q | Mark Scheme | Marks | Marking guidance |
|---|---|---|---|
| **8** (a) | Normal reaction between $P$ and ramp<br>$(R) = 0.3g\cos\alpha = \left(0.3g \times \frac{24}{25} = 2.82...\right)$ | M1 | Seen or implied.<br>Condone sin / cos confusion (implied by use of $\frac{7}{25}$ ) |
| | Work done against friction $= \frac{1}{5}R \times 15$ | M1 | Use of WD $= \mu R \times$ distance with their $R$ |
| | $= 8.47(8.5)(\text{J})$ | A1 | 3 sf or 2 sf |
| | | **3** | |
| **8** (b) | Work-energy equation | M1 | All terms required. Dimensionally correct. Condone sign errors. |
| | $\frac{1}{2} \times 0.3U^2 = \frac{1}{2} \times 0.3 \times 25^2 + (\text{a}) + 0.3 \times g \times (15\sin\alpha)$ | A1ft<br>A1ft | Follow their answer to (a)<br>Correct unsimplified equation with at most one error.<br>Correct unsimplified equation |
| | $U = 27.6 \quad (28)$ | A1 | 3 sf or 2 sf |
| | | **4** | |
| | | | |
| **8** (c) | Time to ground: | M1 | Complete method using *suvat* to form an equation in $t$ |
| | $-15\sin\alpha = 7t - \frac{1}{2}gt^2$ | A1ft | Correct unsimplified equation in $t$ ft their 4.2 |
| | $t = 1.88 \quad (1.9) \quad (\text{s})$ | A1 | 3 sf or 2 sf $\frac{5+\sqrt{67}}{7}$ is A0 |
| | | **3** | |
| **8** (d) | Vertical component of speed | M1 | Or use energy to find the speed |
| | $= \pm(7 - (\text{their } t) \times 9.8) \quad (\pm 11.459....)$ | A1ft | or<br>$0.15 \times 625 + .3 \times 9.8 \times \text{their } 4.2 = 0.15v^2$<br>$(v = 26.59....)$<br>condone $v = \frac{7\sqrt{67}}{5}$ |
| | Correct use of trig: $\tan\theta° = \frac{\text{their vertical}}{24}$ | M1 | or $\cos\theta° = \frac{24}{\text{their speed}}$ |
| | $\theta = 25.5\,(26)$ | A1 | 3 sf or 2 sf |
| | | **4** | |
| | Reminder: The accuracy penalty for overspecified answers should be applied only once in any question (the first time seen). Similarly for the use of $g$ = 9.81. If they make both of these errors they lose 2 A marks. The penalty applies to the final mark in any part. | | |
| | | **(14)** | |

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