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# Mark Scheme (Results)

## January 2024

### 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
   - $\lfloor$ 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.

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# General Principles for Mechanics Marking

*(NB 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 | Right hand side |
| LHS | Left hand side |

| | | | |
|---|---|---|---|
| 1a | Use of $v = \frac{\mathrm{d}x}{\mathrm{d}t}$ | M1 | At least 2 powers going down by 1.<br>Clear division by $t$ is M0 |
| | $v = 6t^2 - 42t + 60$ | A1 | Correct only |
| | Set $v = 0$ and correctly solves to obtain 2 values for $t$ | M1 | Complete method to obtain both values<br>(implied by correct answers seen)<br>$\left(0 = t^2 - 7t + 10 = (t-2)(t-5)\right)$ |
| | Obtain $t = 2$ and $t = 5$ | A1 | Correct only. Allow 2.0, 5.0 |
| | | **[4]** | |
| 1b | Distance $= \lvert x_2 - x_1 \rvert + \lvert x_3 - x_2 \rvert$<br>$\left(= \lvert 45 - 52 \rvert + \lvert 52 - 41 \rvert\right)$ | M1 | Correct strategy dependent on their $t$ being in $1 < t < 3$ |
| | $= 11 + 7 = 18\,(\mathrm{m})$ | A1 | Correct only |
| | | **[2]** | |
| 1c | Use of $a = \frac{\mathrm{d}v}{\mathrm{d}t}$ | M1 | Differentiate their $v$.<br>Clear division by $t$ is M0.<br>A power going down by 1<br>$(a = 12t - 42)$ |
| | Obtain $6\left(\mathrm{m\,s^{-2}}\right)$ | A1 | Must be positive – the Q asks for magnitude |
| | | **[2]** | |
| | | **(8)** | |
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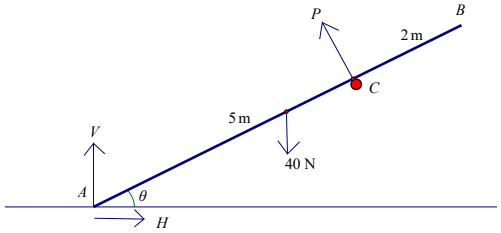
| | | | |
|---|---|---|---|
| 2a | Use of $\mathbf{I} = m\mathbf{v} - m\mathbf{u}$ | M1 | NB: Column vectors are acceptable.<br>Condone wrong order but must be subtracting.<br>Condone 5 in place of 0.5. |
| | $2\mathbf{i} + 5\mathbf{j} = 0.5\left(\mathbf{v} - \left(3\mathbf{i} + \mathbf{j}\right)\right)$<br><br>$\left(\mathbf{v} = 7\mathbf{i} + 11\mathbf{j}\right)$ | A1 | Correct unsimplified equation<br>Accept as a vector equation or as a pair of equations, one for each component.<br>Accept alternative notations provided the meaning is clear. |
| | Use of Pythagoras | M1 | For their **v**<br>Independent M1 but they must have a **v** |
| | $\lvert v\rvert = \sqrt{121+49} = \sqrt{170}\ \left(\text{m s}^{-1}\right)$ | A1 | $13\left(\text{m s}^{-1}\right)$ or better. (13.038…….) |
| | | **[4]** | |
| | | | |
| 2b | Correct use of trigonometry e.g.<br>$\theta = \tan^{-1}\frac{11}{7} - \tan^{-1}\frac{1}{3}$<br>$\left(= 57.5 - 18.4\right)$ | M1 | Condone subtraction in either order.<br>Allow if **both** fractions are the other way up.<br>Alternatives:<br>scalar product<br>$\theta = \cos^{-1}\left(\frac{21+11}{\sqrt{10}\sqrt{170}}\right)$<br>cosine rule<br>$4\times 29 = 10 + 170 - 2\sqrt{10}\sqrt{170}\cos\theta$ |
| | $\theta = 39.1$ | A1 | Accept $\pm 39$ or better (39.0938…)<br>0.68(2) radians is M1A0<br>Accept $\pm\left(360 - 39\right) = \pm 321$ or better |
| | | **[2]** | |
| | | **(6)** | |
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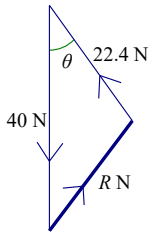
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|---|---|---|---|
| 3a | $F_{\max} = \frac{1}{3} \times 2g\cos\alpha \left(= 5.90...\right)$ | M1 | Use of $F = \mu R$<br>Seen or implied.<br>Condone sine / cosine confusion<br>Condone $g$ missing |
| | WD against friction $= 6 \times$ *their* $F_{\max}$ | M1 | $\left(= 35.4...(\text{J})\right)$ Seen or implied as part of the 4th M mark |
| | PE gain $= 2g \times 6 \times \sin\alpha$<br>$\left(= 6 \times \frac{42}{5} = 50.4\right)$ | M1 | dimensionally correct. Condone sine / cosine confusion |
| | Total WD = WD against friction + WD against gravity (gain in PE) | DM1 | Dependent on the 3 preceding M marks. Require both terms and no extras |
| | Total WD $= 85.8\left(\text{J}\right)$ or $86\left(\text{J}\right)$ | A1 | 3 sf or 2 sf only<br>$\left(8\sqrt{10} + 36\right)\frac{g}{7}$ is A0 (incorrect units) |
| | NB a candidate who resolves parallel to the slope but never multiplies either component by 6 will score the first M1 only | | |
| | | **[5]** | |
| 3b | Work-energy equation<br>(KE gained = loss in GPE - WD against friction) | M1 | Must be using work-energy.<br>Need all terms, no extras and dimensionally correct.<br>Condone sign errors<br>Condone sine / cosine confusion. |
| | $\frac{1}{2} \times 2v^2 = 2g \times 6\sin\alpha - 6 \times \frac{2}{3} g\cos\alpha$ | A1<br>A1 | Unsimplified equation with at most one error<br>Correct unsimplified equation.<br><br>They must have started with correct expressions, but follow through on any calculation errors |
| | $v = 3.87\left(\text{m s}^{-1}\right)$ *or* $3.9\left(\text{m s}^{-1}\right)$ | A1 | 3 sf or 2 sf only |
| | | **[4]** | |
| | | **(9)** | |
| | | | |

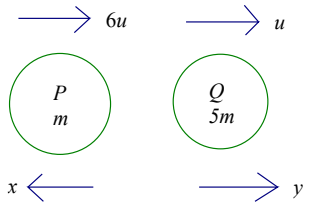
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|---|---|---|---|
| 4a | If the division of the shape involves non-standard shapes (e.g. a trapezium) the centres of mass must be quoted correctly or a correct method used to find the position to score any marks. | | |
| | <table><tr><td>rectangle</td><td>-triangle</td><td>+triangle</td></tr><tr><td>$20a^2$</td><td>$-\frac{9}{2}a^2$</td><td>$\frac{9}{2}a^2$</td></tr><tr><td>$2a$</td><td>$3a$</td><td>$2a$</td></tr></table> or <table><tr><td>rectangle</td><td>rectangle</td><td>Double triangle</td></tr><tr><td>$3a^2$</td><td>$8a^2$</td><td>$9a^2$</td></tr><tr><td>$\frac{1}{2}a$</td><td>$2a$</td><td>$2a$</td></tr></table> or <table><tr><td>rectangle</td><td>trapezium</td><td>triangle</td></tr><tr><td>$5a^2$</td><td>$\frac{21}{2}a^2$</td><td>$\frac{9}{2}a^2$</td></tr><tr><td>$\frac{1}{2}a$</td><td>$\frac{48}{21}a$</td><td>$2a$</td></tr></table> | B1<br><br>B1 | Correct mass ratios for a correct division of the folded template and correct total of $20a^2$<br>Correct distances from $AD$ seen or implied.<br>B0B1 is possible if they have incorrect masses but a full set of correct distances. e.g. if they use the second alternative but have not doubled the triangle. Or they might have a correct split with an error in one of the areas or an incorrect (or missing) total<br><br>or equivalent |
| | Moments about $AD$ or a parallel axis. | M1 | Dimensionally consistent.<br>All terms for a correct division of $L$ and no extras.<br>Accept as part of a vector equation |
| | $40a^3 - \frac{27}{2}a^3 + 9a^3 = 20a^2d$<br>or $\frac{3}{2}a^3 + 16a^3 + 18a^3 = 20a^2d$<br>or $\frac{2}{2}a^3 + \frac{48}{2}a^3 + 9a^3 = 20a^2d$ | A1 | Correct unsimplified equation for their axis. Allow for correct component in a vector equation. |
| | $d = \frac{71}{40}a$ * | A1* | Obtain given answer from correct working. Need at least one line of working to **collect like terms** e.g. $20d = \frac{71}{2}a$ Final answer must be as printed i.e. $d = \ldots$. |
| | | **[5]** | |
| 4b | Moments about $S$ | M1 | A complete method to get an equation in $W$ and $F$ only.<br>Need all terms and no extras.<br>Dimensionally consistent. |
| | NB If they start by finding the centre of mass for the system they do not score marks until they form the moments equation.<br>If they are clearly using moments about $A$ (e.g. $d$ and $4a$ used as distances in their equation) this is M0 unless they include the reaction at $S$ and resolve to form the required equation.<br>If they say they are using moments about $S$ and have just one incorrect distance allow M1A1A0A0 | | |
| | $4W \times \frac{31}{40}a + W \times 3a = F \times 5a$<br>or $(4W + W)(2.22a - a) = 5aF$ | A1<br><br>A1 | Unsimplified equation with at most one error<br>Correct unsimplified equation |
| | $F = \frac{61}{50}W$ | A1 | Accept $1.22W$ or $1.2W$ |
| | | **[4]** | |
| | | **(9)** | |

| | | | |
|---|---|---|---|
| 5a | Use of $P = Fv$ | M1 | $\frac{10000}{16}(=625)$ o.e. seen or implied in the working.<br>Allow for $\frac{10}{16}$ |
| | Equation of motion for the system | M1 | Dimensionally correct. Need all terms and no extras. Condone sign errors and sine/cosine confusion<br>If they start with separate equations for the van and trailer, just mark the combined equation. |
| | $F - 400 - 800g\sin\alpha = 800a$ | A1<br><br>A1 | Unsimplified equation in $P$ or $F$ with a most one error<br>Correct unsimplified equation in $P$ or $F$<br>Use of cosine in place of sine for both vehicles counts as a repeated error and only loses 1 mark |
| | Obtain deceleration<br>$0.419\left(\text{m s}^{-2}\right)$ or $0.42\left(\text{m s}^{-2}\right)$ | A1 | 3 sf or 2 sf only<br>Answer must be positive. |
| | | **[5]** | |
| 5b | Equation of motion for the van or the trailer | M1 | Dimensionally correct. Need all terms and no extras. Condone sign errors and sine/cosine confusion<br>Use the mass in the *ma* term to decide which part of the system they are using. |
| | $T - 150 - 200g\sin\alpha = 200a$<br>or $F - T - 250 - 600g\sin\alpha = 600a$ | A1<br><br>A1 | Unsimplified equation with at most one error<br>Correct unsimplified equation |
| | Obtain tension $206(\text{N})$ or $210(\text{N})$ | A1 | 3 sf or 2 sf only |
| | | **[4]** | |
| | | **(9)** | |
| | | | |

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|---|---|---|---|
| 6a |  | | |
| | Moments about $A$: | M1 | Dimensionally correct. Condone sine / cosine confusion |
| | $5P = 40 \times \frac{7}{2}\cos\theta$ | A1 | Correct unsimplified equation |
| | $P = 22.4$ * | A1* | Obtain **given answer** from correct working.<br>Need to see evidence of $\cos\theta = \frac{4}{5}$ |
| | | **[3]** | |
| 6b | Two equations required. M1A1 for the first equation seen, M1A1 for the second equation. If more than 2 equations mark the two equations used to obtain the resultant, or the best 2 if they do not go on to find the resultant. | | |
| | First equation | M1 | e.g. Resolve horizontally Condone sine / cosine confusion |
| | $H = P\sin\theta\,(=13.44)$ | A1 | Correct unsimplified equation |
| | Second equation | M1 | e.g. Resolve vertically Condone sine / cosine confusion |
| | $V + P\cos\theta = 40\,(V = 22.08)$ | A1 | Correct unsimplified equation |
| | $\lvert R\rvert = \sqrt{H^2 + V^2}$ | DM1 | solve for $\lvert R\rvert$<br>Dependent on the 2 preceding Ms |
| | $\lvert R\rvert = 26\,(\text{N})$ | A1 | Or better (25.84879…..)<br>Accept $\frac{24\sqrt{29}}{5}$ |
| | | **[6]** | |
| | Two alternatives on following page | | |

| | | | |
|---|---|---|---|
| 6balt | First equation | M1 | e.g. Resolve parallel Condone sine / cosine confusion |
| | $X = 40\sin\theta\,(=24)$ | A1 | Correct unsimplified equation |
| | Second equation | M1 | e.g. Resolve perpendicular Condone sine / cosine confusion |
| | $Y + P = 40\cos\theta\,(Y = 9.6)$ | A1 | Correct unsimplified equation |
| | $\lvert R\rvert = \sqrt{X^2 + Y^2}$ | DM1 | solve for $\lvert R\rvert$<br>Dependent on the 2 preceding Ms |
| | $\lvert R\rvert = 26\,(\text{N})$ | A1 | Or better (25.84879…..)<br>Accept $\frac{24\sqrt{29}}{5}$ |
| | | **[6]** | |
| | Alternative equations:<br>$\text{M}(C)\quad 40\times 1.5\cos\theta + H\times 5\sin\theta = V\times 5\cos\theta$<br>$\text{M}(B)\quad 2P + 7\cos\theta\times V = 7\sin\theta\times H + 3.5\times 40\cos\theta$<br>$\text{M}(G)\quad 1.5P + 3.5\sin\theta\times H = 3.5\cos\theta\times V$ | | |
| | | | |
| 6balt |  | M1<br>A1 | 3 force diagram seen or implied<br>Forces and angle in correct positions |
| | Use Cosine Rule | M1 | Correct formula used |
| | $(\lvert R\rvert)^2 = 40^2 + 22.4^2 - 2\times 40\times 22.4\cos\theta$ | A1 | Correct unsimplified equation |
| | Substitute for trig and solve for $\lvert R\rvert$ | DM1 | Dependent on the 2 preceding Ms |
| | $\lvert R\rvert = 26\,(\text{N})$ | A1 | Or better (25.84879…..)<br>Accept $\frac{24\sqrt{29}}{5}$ |
| | | **[6]** | |
| | | | |
| | | **(9)** | |

| | | | |
|---|---|---|---|
| 7a |  | | If $6u$ and $u$ are in opposite directions, mark as a sign error. |
| | Use of CLM | M1 | Need all 4 terms. Dimensionally consistent. Condone sign errors<br>Condone $x$ in the wrong direction |
| | $6mu+5mu=5my-mx$<br>$(11u=5y-x)$ | A1 | Correct unsimplified equation |
| | Use of impact law | M1 | Used correctly. Dimensionally correct. Condone sign errors |
| | $x+y=5eu$ | A1 | Correct unsimplified equation. Signs consistent with their CLM equation |
| | Solve for $x$ in terms of $e$ and $u$:<br>$6x=25eu-11u$<br>or solve for $e$ in terms of $y$ and $u$: $e=\frac{6y-11u}{5u}$ | DM1 | Dependent on the first 2 M marks. As far as $kx=..$<br>Dependent on the previous 2 M marks |
| | Use $x>0$ $(\Rightarrow y>\frac{11}{5}u)$: $25e>11$ | DM1 | Use correct inequality for their $x$ |
| | $\frac{11}{25}<e(,,1)$ | A1 | Or equivalent. Condone if 1 not mentioned. Allow with <1. A0 if incorrect upper limit. cso |
| | | **[7]** | |
| 7b | $x=\frac{2}{3}u$ and $y=\frac{7}{3}u$ | B1 | Seen or implied |
| | Total KE lost<br>$=\left(\frac{1}{2}m\times36u^2+\frac{1}{2}5m\times u^2\right)$<br>$-\left(\frac{1}{2}m\times x^2+\frac{1}{2}5m\times y^2\right)$ | M1 | Complete expression. Dimensionally correct. Correct masses connected to correct speeds. Condone subtraction in the wrong order. Allow in $x$ and $y$ |
| | $=\left(\frac{1}{2}m\times36u^2+\frac{1}{2}5m\times u^2\right)$<br>$-\left(\frac{1}{2}m\times\frac{4}{9}u^2+\frac{1}{2}5m\times\frac{49}{9}u^2\right)$ | A1ft | Correct unsimplified expression in $m$ and $u$. Follow their $x$, $y$ with $e$ substituted |
| | $=\frac{20}{3}mu^2$ | A1 | Or single term equivalent.<br>Accept $6.7mu^2$ or better |
| | | **[4]** | |
| 7c | velocity of $Q$ after collision with wall<br>$=\pm fy$ $\left(=\pm f\times\frac{7}{3}u\right)$ | B1ft | Follow their $y$ (in terms of $u$) |
| | Second collision if $fy>x$ $\frac{7}{3}fu>\frac{2}{3}u$ | DM1 | Correct inequality for their $x$, $y$<br>Dependent on the B1 and $P$ moving away from the wall |
| | $\frac{2}{7}<f,,1$ | A1 | Correct only<br>Need both limits |
| | | **[3]** | |
| | | **(14)** | |
| 8a | Use symmetry to find time taken:<br>$-7=7-gt$ | M1 | 0r equivalent complete method using *suvat* to find the time taken e.g. find the time for vertical distance = 0 |

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|---|---|---|---|
| | $t = \frac{14}{g} \left(= 1.428...\right)$ | A1 | Correct value seen or implied |
| | Horizontal distance $= 4t$ | DM1 | Complete method using *suvat* to find the distance. Dependent on the preceding M1 |
| | $= 5.71\left(\text{m}\right)$ or $5.7\left(\text{m}\right)$ | A1 | 3 sf or 2 sf only $\frac{40}{7}$ scores A0<br>$\frac{56}{g}$ scores A0 (incorrect units) |
| | | **[4]** | |
| 8a alt | Find speed and angle of projection | M1 | Correct use of Pythagoras and trig. |
| | Speed $= \sqrt{16+49} = \sqrt{65}\ \left(\text{m s}^{-1}\right)$<br>Direction $= \tan^{-1}\frac{7}{4} \quad \left(= 60.3°\right)$ | A1 | Both values seen or implied. |
| | Use of $R = \frac{u^2 \sin 2\alpha}{g}$ | DM1 | Or equivalent. Dependent on the preceding M1 |
| | $= 5.71\left(\text{m}\right)$ *or* $5.7\left(\text{m}\right)$ | A1 | 3 sf or 2 sf only |
| | | **[4]** | |
| 8b | $\lvert\mathbf{v}\rvert = 5 \Rightarrow \mathbf{v} = 4\mathbf{i} + 3\mathbf{j}$ or $\mathbf{v} = 4\mathbf{i} - 3\mathbf{j}$ | B1 | Correct vertical component seen or implied |
| | $-3 = 3 - gT$ | M1 | Complete method to find $T$<br>e.g. $T = \frac{14}{g} - 2 \times \frac{4}{g}$ |
| | $T = 0.612$ or $T = 0.61$ | A1 | 3 sf or 2 sf only $\frac{30}{49}$ scores A0<br>$\frac{6}{g}$ scores A0 (incorrect units) |
| | | **[3]** | |
| 8c | $\begin{pmatrix}4\\7\end{pmatrix} \cdot \begin{pmatrix}4\\p\end{pmatrix} = 0$ | M1 | Or equivalent method to find perpendicular velocity |
| | $\Rightarrow p = -\frac{16}{7}, \quad \mathbf{v} = 4\mathbf{i} - \frac{16}{7}\mathbf{j}$ | A1 | Correct vertical component<br>Allow -2.28…. |
| | $\left((-)\frac{16}{7}\right)^2 = 7^2 - 2gh$ | DM1 | Complete method using *suvat* or energy to form an equation in $h$ only.<br>Dependent on the preceding M1 |
| | $h = 2.23$ or $h = 2.2$ | A1 | 3 sf or 2 sf only cso (negative vertical component seen at some point) |
| | | **[4]** | |
| 8c alt | $\begin{pmatrix}4\\7\end{pmatrix} \cdot \begin{pmatrix}4\\7-gt\end{pmatrix} = 0$ | M1 | Or equivalent method to find time when velocity perpendicular |
| | $t = \frac{65}{7g} \left(= 0.947...\right)$ | A1 | Correct time |
| | $h = 7t - \frac{1}{2}gt^2$ | DM1 | Complete method using *suvat* to form an equation in $h$ only. |
| | $h = 2.23$ or $h = 2.2$ | A1 | 3 sf or 2 sf only cso |
| | | **[4]** | |
| | | **(11)** | |

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