Pearson Edexcel

# Mark Scheme (Results)

## October 2020

### Pearson Edexcel International Advanced Level In Mechanics M2 (WME02/01)

| Question Number | Solution | Marks | Notes |
|---|---|---|---|
| 1. | $\mathbf{I} = 2\left[\lambda\mathbf{i} + \lambda\mathbf{j} - 5\mathbf{i} - 3\mathbf{j}\right]$ | M1 | Use of $\mathbf{I} = m\left(\mathbf{v} - \mathbf{u}\right)$ |
| | $= 2\left(\lambda - 5\right)\mathbf{i} + 2\left(\lambda - 3\right)\mathbf{j}$ | A1 | Any equivalent form |
| | $\left\|I\right\| = \sqrt{40} \Rightarrow \left(\lambda - 5\right)^2 + \left(\lambda - 3\right)^2 = 10$ | M1 | Correct use of Pythagoras and their impulse to form an equation in $\lambda$ |
| | $\lambda^2 - 8\lambda + 12 = 0 \Rightarrow \lambda = 2$ or $\lambda = 6$ | DM1 | Solve to find both values for $\lambda$.<br>Dependent on the 2 preceding M marks |
| | $\mathbf{I} = -6\mathbf{i} - 2\mathbf{j}$ or $\mathbf{I} = 2\mathbf{i} + 6\mathbf{j}$<br>$(a = -6, b = -2$ or $a = 2, b = 6)$ | A1 | And no others |
| | | **(5)** | |
| | Alternative working: | | |
| | $\mathbf{I}\left(= a\mathbf{i} + b\mathbf{j}\right) = 2\left(\mathbf{v} - \left(5\mathbf{i} + 3\mathbf{j}\right)\right)$ | M1A1 | |
| | $\mathbf{v} = \frac{a+10}{2}\mathbf{i} + \frac{b+6}{2}\mathbf{j} \quad \Rightarrow \quad \left(\Rightarrow a + 10 = b + 6\right)$ | | |
| | $a^2 + b^2 = 40 \Rightarrow b^2 - 4b - 12 = 0$<br>or $a^2 + 4a - 12 = 0$ | M1 | Correct use of Pythagoras and impulse to form an equation in $a$ or $b$<br>Any equivalent form |
| | $b^2 - 4b - 12 = 0 \quad \Rightarrow b = 6$ or $b = -2$ | DM1 | |
| | $\mathbf{I} = -6\mathbf{i} - 2\mathbf{j}$ or $\mathbf{I} = 2\mathbf{i} + 6\mathbf{j}$ | A1 | Or simplified equivalent |
| | | **[5]** | |

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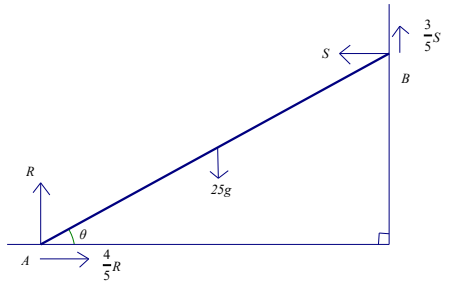
|---|---|---|---|
| 2 | Driving force $= \dfrac{3P}{12}$ | B1 | Use of $P = Fv$<br>Allow for $\dfrac{P}{12}$ in second equation if not awarded here |
| | | | |
| | Motion up the hill<br>$F - R - W\sin\theta = 0$ | M1 | Need all terms. Condone sign errors and sin/cos confusion. |
| | $\dfrac{3P}{12} - R - \dfrac{9000}{15} = 0$<br>$\left(\dfrac{3P}{12} - R = 600\right)$ | A1 | Correct substituted equation<br>Any equivalent form |
| | Motion down the hill<br>$F + W\sin\theta - R = \dfrac{9000}{9.8} \times \dfrac{9.8}{20}$ | M1 | Need all terms. Condone sign errors and sin/cos confusion. |
| | $\dfrac{P}{12} + \dfrac{9000}{15} - R = 450$<br>$\left(\dfrac{P}{12} - R = -150\right)$ | A1<br>A1 | Substituted equation with at most one error. Any equivalent form.<br>Correct substituted equation. Any equivalent form. |
| | Solve for $P$ or $R$ | DM1 | Dependent on both preceding M marks |
| | $\left(\dfrac{2P}{12} = 750\right) \Rightarrow P = 4500$ | A1 | One correct |
| | $R = 525$ (530) | A1 | Both correct |
| | | **(9)** | |
| SC1 | Misread mass = 9000kg<br>Gives equations $\dfrac{P}{4} = R + 5880$<br>$\dfrac{P}{12} = R - 1470$<br>Solutions: $P = 44100, R = 5145$ | | B1<br>M1A0<br>M1A1ftA0<br>M1A1ftA1ft<br>Total 7/9 |
| SC2 | Use of mass = weight = 9000<br>Gives equations $\dfrac{P}{4} = R + 600$<br>$\dfrac{P}{12} = R + 3810$<br>Solutions: $P = -19260, R = -5415$ | | B1<br>M1A1<br>M1A1A0<br>M1A0A0<br>Total 6/9 |
| | | **[9]** | |

| Question | Solution | Marks | Notes |
|---|---|---|---|
| 3 |  | | |
| | Use of $F = \mu R$ | B1 | At least once |
| | Resolve horizontally | M1 | Allow with their horizontal friction |
| | $S = \frac{4}{5}R \quad (S = F_A)$ | A1 | Correct unsimplified equation |
| | Resolve vertically | M1 | Allow with their vertical friction |
| | $\frac{3}{5}S + R = 25g \quad F_B + R = 25g$<br>$\left(\frac{3}{5}S + \frac{5}{4}S = 25g, \quad S = \frac{500}{37}g\right)$ | A1 | Correct unsimplified equation |
| | Moments equation | M1 | Any moments equation. Need all terms & dimensionally correct |
| | M($A$): $25g \times 1.5\cos\theta = S \times 3\sin\theta + \frac{3}{5}S \times 3\cos\theta$<br>$\left(25g\cos\theta - \frac{6}{5}S\cos\theta = 2S\sin\theta\right)$<br>M($B$): $R \times 3\cos\theta = 25g \times 1.5\cos\theta + \frac{4}{5}R \times 3\sin\theta$ | A1 | Correct unsimplified equation |
| | M1A1 for first equation, M1A1 for second equation, M1A1 for third equation (i.e. mark in the order in which they appear rather than as listed on the mark scheme).<br>If there are more than 3 equations, mark the 3 used or the best 3 if they go no further.<br>Can also be solved using one resolution and two moments equations.<br>Friction acting in the wrong direction scores A0. | | |
| | $\tan\theta = \left(\frac{25g - \frac{6}{5}S}{2S} = \right)\frac{25 - \frac{600}{37}}{\frac{1000}{37}}$ | DM1 | Substitute to form equation in $\tan\theta$ only<br>Condone in decimals<br>Dependent on M marks for the equations |
| | $= \frac{325}{1000}\left(= \frac{13}{40}\right)$ | A1 | Or exact equivalent (0.325) |
| | | **(9)** | |
| SC | It is possible to solve by resolving horizontally or vertically and taking moments about the centre:<br>$1.5\cos\theta \times R = 1.5\cos\theta \times \frac{3}{5}S$<br>$+1.5\sin\theta \times S + 1.5\sin\theta \times \frac{4}{5}R$ | | M1A1 for a correct resolution<br>M2A2 for a complete sets of equations to solve |
| | | **[9]** | |

| Question Number | Solution | Marks | Notes |
|---|---|---|---|
| 4a | <table><tr><td></td><td>*ABCD*</td><td>*PQRV*</td><td>*RSTU*</td><td>*L*</td></tr><tr><td>Mass ratio</td><td>64</td><td>4</td><td>16</td><td>44</td></tr><tr><td>c of m from *AD*</td><td>4*a*</td><td>2*a*</td><td>5*a*</td><td>(*d*)</td></tr></table> | B1<br><br>B1 | Correct mass ratios for their split<br><br>Correct distances from vertical axis for their split<br>Must be multiples of *a* |
| | M(*AD*) | M1 | Moments about *AD* or a parallel axis. Need all terms and dimensionally consistent. |
| | $64\times 4a-4\times 2a-16\times 5a=44d$ | A1 | Correct unsimplified equation<br>Accept as part of a vector equation |
| | $\Rightarrow d=\frac{168}{44}a=\frac{42}{11}a$ * | A1* | Obtain **given answer** from correct working |
| | | **(5)** | |
| 4b | C of M of *L* lies at midpt of *AC* | B1 | Seen or implied |
| | M(Mid pt *AB*) | M1 | Use of moments to form equation in *k*. |
| | $\left(4-\frac{42}{11}\right)aM=4akM$ | A1 | Correct unsimplified equation.<br>Allow with *a* not seen |
| | $k=\frac{1}{22}$ | A1 | 0.05 or better (0.0454545…)<br>Allow with *a* not seen |
| | | **(4)** | |
| 4b alt | C of M of *L* lies at midpt of *AC* | B1 | Seen or implied by use of $\bar{x}=\bar{y}$ or $\tan 45°=1$ |
| | Find $\bar{x}$ and $\bar{y}$ for system | M1 | |
| | From *AB*: $\frac{42}{11}Ma+8akM=(1+k)M\bar{y}$<br>From *BC*: $\frac{46}{11}aM=(1+k)M\bar{x}$ | A1 | Correct unsimplified equations in $\bar{x}$ and $\bar{y}$<br>Allow with *a* not seen |
| | $\bar{x}=\bar{y}\Rightarrow\frac{42}{11}+8k=\frac{46}{11}\Rightarrow k=\frac{1}{22}$ | A1 | Allow with *a* not seen |
| | | | |
| 4b alt | C of M of *L* lies at midpt of *AC* | B1 | Seen or implied in moments equation |
| | If *G* is c of m of *L* then $\tan ABG=\frac{42}{46}$ and take moments about *B* | M1 | Complete method for moments about *B* |
| | $8a\sin 45°\times kM$<br>$=\frac{Ma\sqrt{46^2+42^2}}{11}\sin(45°-ABG)$ | A1 | Correct unsimplified equation in *k*<br><br>Allow with *a* not seen |
| | $\Rightarrow k=\frac{1}{22}$ | A1 | Allow with *a* not seen |
| | | | |
| 4b alt | C of M of *L* lies at midpt of *AC* | B1 | Seen or implied in moments equation |

| | | | |
|---|---|---|---|
| | Take moments about the centre of *ABCD* | M1 | |
| | $M \times \frac{2\sqrt{2}}{11} a = kM \times 4\sqrt{2}a$ | A1 | Correct unsimplified equation in $k$<br>Allow with $a$ not seen |
| | $\Rightarrow k = \frac{1}{22}$ | A1 | Allow with $a$ not seen |
| | | **[9]** | |
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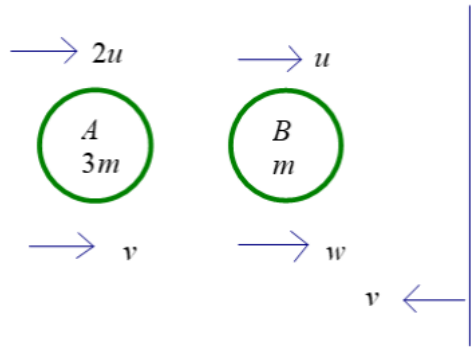
| | | | |
| Question Number | Solution | Marks | Notes |
| 5a | $\mathbf{a} = \frac{\mathrm{d}\mathbf{v}}{\mathrm{d}t}$ | M1 | Differentiate to obtain **a** – powers going down |
| | $= (6t - 9)\mathbf{i} + (2t + 1)\mathbf{j}$ | A1 | differentiation correct |
| | $= 9\mathbf{i} + 7\mathbf{j}$ $(\mathrm{m\,s^{-2}})$ | A1 | ISW if go on to find $\lvert\mathbf{a}\rvert$ |
| | | **(3)** | |
| | | | |
| 5b | Instantaneous rest $\Rightarrow \mathbf{v} = 0\mathbf{i} + 0\mathbf{j}$<br>$\Rightarrow 3(t-1)(t-2) = 0$<br>and $(t-2)(t+3) = 0$ | M1 | Set **v** = 0 and solve for $t$<br>(Need **both components** equal to zero) |
| | $\Rightarrow t = 2$ | A1 | |
| | $\mathbf{r} = \int \mathbf{v}\mathrm{d}t$ | M1 | Integrate to obtain **r** – powers going up. Condone if no constant of integration seen. |
| | $= \left(t^3 - \frac{9}{2}t^2 + 6t\right)\mathbf{i} + \left(\frac{1}{3}t^3 + \frac{1}{2}t^2 - 6t\right)\mathbf{j}$ | A1<br>A1 | At most one error<br>Correct integration<br>Allow column vector.<br>Allow A1A0 for correct integration and non-zero constants(s) of integration |
| | $= 2\mathbf{i} - \frac{22}{3}\mathbf{j}$ , distance $= \sqrt{2^2 + \left(\frac{22}{3}\right)^2}$ | DM1 | Correct strategy to find the distance, i.e. substitute their value for $t$ and use Pythagoras<br>Dependent on the two preceding M marks |
| | $= \frac{2\sqrt{130}}{3} = 7.60$ (m) | A1 | 7.6 or better from correct work |
| | | **(7)** | |
| | | **[10]** | |

| Question Number | Solution | Marks | Notes |
|---|---|---|---|
| 6a | $R = 6g\cos\alpha$ | B1 | Correct normal reaction |
| | Work done $= 15\times 0.25\times R$ | M1 | Correct method with their $R$ |
| | $= 204\,(\text{J})$ | A1 | Or 200(J)<br>Accept $21g$ or better. (20.7692...$g$)<br>Not $\frac{2646}{13}$ |
| | | **(3)** | |
| | | | |
| 6b | NB The question specifies that the work-energy principle should be used, so solutions based on *suvat* equations are not accepted. | | |
| | Initial KE – GPE lost – WD = final KE | M1 | Use of work-energy to form equation in $v$. Dimensionally correct. Ignore sign errors.<br>Allow WD or their WD |
| | $\frac{1}{2}\times 6\times 14^2 - 6g\times 15\times\frac{5}{13} - 6g\times 15\times\frac{3}{13}$<br>$= \frac{1}{2}\times 6v^2$<br>$\left(3\times 196 - \frac{450g}{13} - \frac{270g}{13} = 3v^2\right)$ | A1ft<br>A1ft | Unsimplified equation with at most one error<br>Correct unsimplified equation<br>Follow their WD |
| | $v = 3.88 \quad (3.9)$ | A1 | Max 3 sf |
| | Work-energy equation | M1 | Complete method using work-energy to form equation in $w$. Dimensionally correct. Ignore sign errors. |
| | $\frac{1}{2}\times 6\times 14^2 - 6g\times 15\times\frac{3}{13} = \frac{1}{2}\times 6w^2$<br>or $\frac{1}{2}mw^2 = \frac{1}{2}mv^2 + mg\times\frac{15\times 5}{13}$ | A1ft | Correct unsimplified equation<br>Follow their WD or their $v$ |
| | $w = 11.3 \quad (11)$ | A1 | Max 3 sf |
| | | **(7)** | |
| | | **[10]** | |

| Question Number | Solution | Marks | Notes |
|---|---|---|---|
| 7 |  | | |
| 7a | KE gain = final KE – initial KE | M1 | KE equation for *B*.<br>Allow for change in KE |
| | $\frac{48}{25}mu^2 = \frac{1}{2}mw^2 - \frac{1}{2}mu^2$ | A1 | Correct unsimplified equation to find *w* |
| | $\left(w^2 = \frac{121}{25}u^2, \quad w = \frac{11}{5}u\right)$ | | |
| | CLM: $3m \times 2u + mu = 3mv + mw$ | M1 | All terms required. Condone sign errors |
| | $\left(7mu = 3mv + \frac{11}{5}mu\right) \left(v = \frac{8}{5}u\right)$ | A1 | Correct unsimplified equation in *v* and *w* or their *w* |
| | Impact law: | M1 | Used correctly |
| | $w - v = e(2u - u)$ | A1 | Correct unsimplified equation in *v* and *w* or their *v* and *w* |
| | Solve for *e* | DM1 | Dependent on the preceding M marks |
| | $\frac{3}{5}u = eu, \quad e = \frac{3}{5}$ | A1 | |
| | | **(8)** | |
| 7b | Impact law: $fw = v$ | M1 | Condone sign error |
| | $f = \frac{8}{11}$ | A1 | 0.73 or better<br>Final answer must be positive |
| | | **(2)** | |
| | | **[10]** | |

| Question Number | Solution | Marks | Notes |
|---|---|---|---|
| 8a | Horizontal component: $p = 8$ | B1 | |
| | Vertical component: $-12 = q - 3g$ | M1 | Complete method to find $q$ using *suvat*. Condone sign errors. |
| | $q = 17.4$ | A1 | 17 or better |
| | Speed $= \sqrt{8^2 + 17.4^2}$ | M1 | Use of Pythagoras to find speed using their velocity.<br>Independent M mark |
| | $= 19.2 \quad (19) \left(\text{m s}^{-1}\right)$ | A1 | 3 sf or 2 sf |
| | | **(5)** | |
| | | | |
| 8b | Use of Pythagoras to find vertical component | M1 | |
| | vertical component $= \pm 6$ | A1 | Seen or implied Accept without +/- |
| | $-6 = 6 - 9.8T$ | DM1 | Complete method using *suvat* to find required time<br>Dependent on the previous M1 |
| | $T = 1.22 \quad (1.2)$ | A1 | 3 sf or 2 sf. Not $\frac{60}{49}$ |
| | | **(4)** | |
| 8b alt | Use *suvat* and Pythagoras to form an equation in $t$ | M1 | Or an inequality |
| | $8^2 + (17.4 - gt)^2 = 100$ | A1 | Correct unsimplified equation for $t$<br>Accept inequality |
| | Solve for $T$ | DM1 | Complete method to obtain $T$<br>Dependent on the previous M1 |
| | $T = 1.22 \quad (1.2)$ | A1 | 3 sf or 2 sf. Not $\frac{60}{49}$ |
| | | **(4)** | |
| | | | |
| 8c | Velocity perpendicular<br>$\Rightarrow$ vertical component $= \frac{2}{3} \times 8$ | M1 | Complete method to find vertical component of velocity at $B$ |
| | $= \frac{16}{3}$ | A1 | |
| | $(-12)^2 = \left(\frac{16}{3}\right)^2 - 2g(-h)$ | DM1 | Complete method to find the required vertical distance using their vertical component of the velocity<br>Dependent on the previous M1 |
| | $h = 5.90 \quad (5.9) (\text{m})$ | A1 | Max 3 sf |
| | | **(4)** | |
| 8c alt | $\begin{pmatrix} 8 \\ 17.4 - gt \end{pmatrix} . \begin{pmatrix} 8 \\ -12 \end{pmatrix} = 0$ and time $= 3 - t$ | M1 | Complete method to find the time from $B$ to $A$ |
| | Time $= 3 - 1.23... = 1.768...$ | A1 | |
| | $s = vt - \frac{1}{2} gt^2 = 12t - 4.9t^2$ | DM1 | Complete method to find the required vertical distance using their time<br>Dependent on the previous M1 |
| | $s = 5.9$ (m) | A1 | Max 3 sf |
| | | | |

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|---|---|---|---|
| | | **[13]** | |